The Engineer

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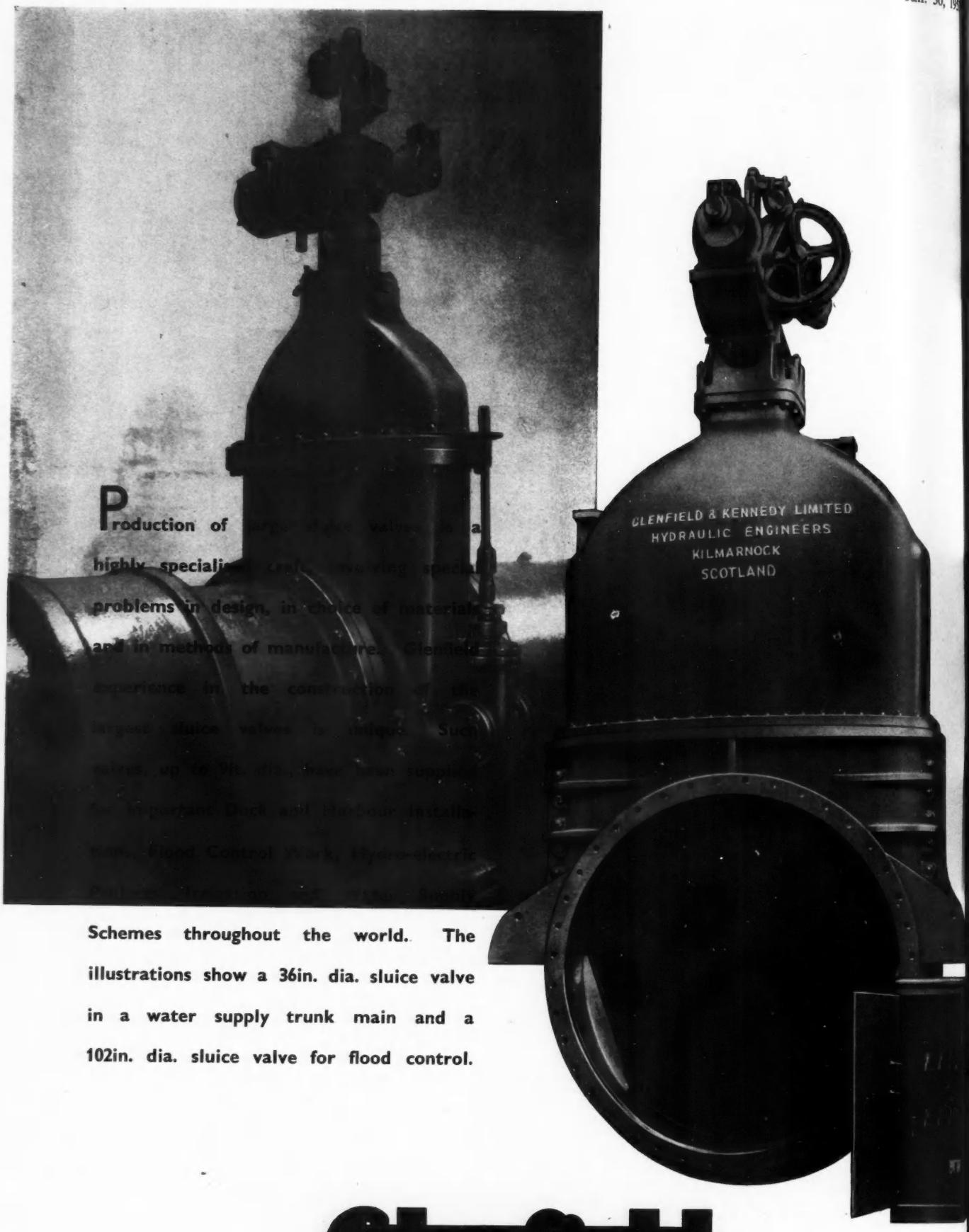

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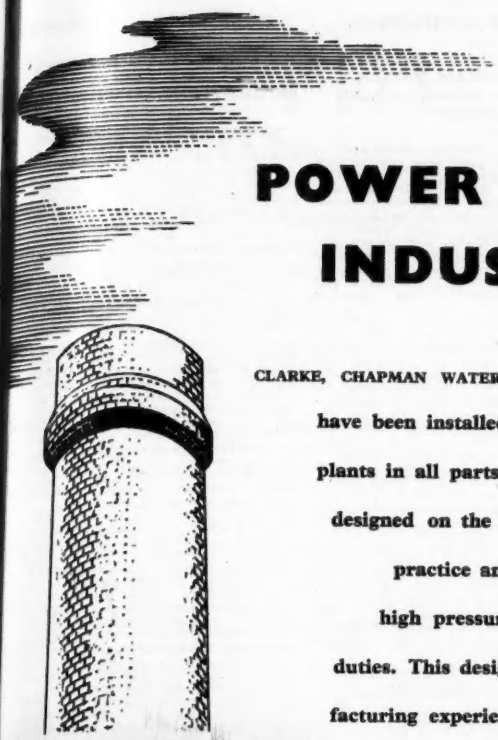

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THE ENGINEER

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PRINCIPAL CONTENTS

(Complete contents on page 174)

The Royal Electrical and Mechanical Engineers ... 174

Sewage-Sludge Digestion Calculations—No. I ... 158
(L. B. ESCRITT)

Welding in Marine Engineering—No. II 160
(H. N. PEMBERTON)

The First Iron Steamer 163
(PHILIP SPRATT)

Some Foreign Civil Engineering Schemes of 1952—No. I 164

Bankside Power Station—No. II 167

Design of Precision Grinding Machines 177

Research and the Gas Turbine 186
(HAYNE CONSTANT)

"Just So" or "Near Enough" 174

NOTICE TO READERS

All letters intended for insertion in 'The Engineer' or containing questions should be accompanied by the name and address of the writer, not necessarily for publication, but as a proof of good faith. No notice whatever can be taken of anonymous communications. No undertaking can be given to return drawings or manuscripts; correspondents are therefore requested to keep copies.

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Advertisements received by Mid-day Tuesday will appear in the issue of Friday the same week. Orders must be accompanied by a remittance.

INDEX TO ADVERTISERS—PAGE 111

PUBLIC APPOINTMENTS

UNIVERSITY OF NOTTINGHAM

DEPARTMENTS OF CIVIL AND MECHANICAL ENGINEERING

DRAUGHTSMAN

DRAUGHTSMAN required to work under the direction of the Professor of Engineering. Salary up to £500 p.a. Application form and conditions of appointment may be obtained from the undersigned.

H. PICKBOURNE,
E7075 Registrar.

WIGAN AND DISTRICT MINING AND TECHNICAL COLLEGE

LECTURER IN ELECTRICAL ENGINEERING

The Governing Body invites applications for a post as LECTURER IN ELECTRICAL ENGINEERING. Duties will commence as soon as possible.

Candidates should hold a Degree in Electrical Engineering and should preferably be able to teach electrical measurements. Experience in industry and/or in teaching is desirable. Salary in accordance with the Burnham Technical Scale for Assistants, Grade "B," with full allowance for industrial and other experience.

Further particulars and application form will be sent by the undersigned on receipt of a stamped, addressed foolscap envelope. Last date for receipt of applications Monday, 9th February, 1953. Applications not on the form provided will be disregarded.

E. C. SMITH,
Principal.
16th January, 1953. E7076

CITY AND COUNTY OF BRISTOL EDUCATION COMMITTEE

COLLEGE OF TECHNOLOGY

Principal : F. W. PARTINGTON, M.Sc.

SENIOR LECTURESHIP

Applications invited for a SENIOR LECTURESHIP in the Engineering Department of the College with main responsibility for Applied Heat and Heat Engines, Theory and Laboratory, with some coverage of other engineering subjects.

Salary scale £1040 by £25 to £1190 per annum. Application forms (returnable as soon as possible after the appearance of this advertisement) and further particulars obtainable by sending stamped, addressed envelope to Registrar, College of Technology, Bristol, 1.

G. H. SYLVESTER,
Chief Education Officer.
Council House,
College Green,
Bristol, 1. E7115

IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY

ENGLISH ELECTRIC COMPANY'S BURSARIES IN HYDRO-POWER ENGINEERING

Notice is hereby given that a number of ENGLISH ELECTRIC COMPANY BURSARS in HYDRO-POWER ENGINEERING will be elected in June, 1953. The Bursaries are of the value of £250 for one year, tenable for post-graduate study in the Civil Engineering Department of the Imperial College. Bursars pay the appropriate College tuition fee, The Bursaries will be recommended for supplementation by the Ministry of Education.

Bursars who successfully complete the course will be eligible for the award of the Diploma of the Imperial College (D.I.C.).

Candidates should have an Honours Degree in Engineering or an equivalent qualification, and applications should be received before 1st June, 1953, by the Deputy Registrar, City and Guilds College, Exhibition Road, London, S.W.7, from whom further details may be obtained. E7148

THE TRAINING OF TECHNICAL TEACHERS

ONE-YEAR COURSE OF TRAINING

TEACHERS OF ENGINEERING AND ALLIED SUBJECTS

Applications are invited from men of about 25 years of age and over for admission to a ONE-YEAR COURSE of TRAINING as full-time TEACHERS of ENGINEERING and ALLIED SUBJECTS in Technical Colleges and similar institutions.

Applicants should have a University Degree, be Associate Members of a Professional Institution, or possess qualifications of the order of Higher National Certificate or Full Technological Certificate of the City and Guilds of London Institute in one of the various branches of engineering, together with suitable experience in industry.

The course will begin in September, 1953. Recognised students will pay no fees and will be eligible for maintenance grants.

Further particulars and application forms may be obtained from the following colleges by sending a stamped, addressed foolscap envelope :—

Bolton : The Director (S/1/7), Bolton Training College, Manchester Road, Bolton, Lancs.

Huddersfield : The Director (S/1/7), Huddersfield Training College, Queen Street South, Huddersfield, Yorks.

London : The Principal (S/1/7), Training College for Technical Teachers, 83, New Kent Road, London, S.E.1. (1221) E6327

PUBLIC APPOINTMENTS

IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY

DEPARTMENT OF CIVIL ENGINEERING

BURSARIES IN CONCRETE TECHNOLOGY

Notice is hereby given that the election to BURSARIES in CONCRETE TECHNOLOGY, tenable as from October, 1953, will take place in June, 1953.

Candidates must hold a Degree in Engineering at the time of taking up the award, and must also have a good knowledge of the theory of structures.

Bursaries are of the value of £350 per annum, out of which the College tuition fee has to be paid ; the amount may be increased to £450 for those with industrial experience. In addition, one or two Senior Bursaries of £600 per annum may be awarded to outstanding men with a minimum of three years' experience in industry.

The course will be post-graduate and Bursars who successfully complete the course will be eligible for the award of the Diploma of the Imperial College (D.I.C.).

Applications must be received on or before June 1st, 1953, by the Deputy Registrar, City and Guilds College, Exhibition Road, London, S.W.7, who will, on written request, send full information and application forms. E7147

THE COLLEGE OF AERONAUTICS

DEPARTMENT OF FLIGHT

RESEARCH ASSISTANT

RESEARCH ASSISTANT required in the Department of Flight. Applicants should possess a Degree in Engineering, Physics or Mathematics, or, alternatively, Higher National Certificate plus good practical training. Previous experience of flight research not essential, but applicants must be willing and fit to fly. Salary, depending upon qualifications, within the range of £300 to £500 per annum. Hostel accommodation available.—Applications, giving full particulars and containing the names and addresses of not more than three referees, to the Registrar, The College of Aeronautics, Cranfield, Bletchley, Bucks. Closing date 20th February, 1953. E7099

DARTFORD TECHNICAL COLLEGE

MACHINE SHOP PRACTICE CLASSES

ASSISTANT (GRADE "A")

ASSISTANT (Grade "A") required for Machine Shop Practice Classes, City and Guilds and National Certificate Examinations, and to take charge of the College workshops. Applicants must be skilled in modern machine shop methods and should have had experience of instructing apprentices. Preference will be given to applicant holding appropriate City and Guilds or National Certificates who can offer workshop science in addition to practice.—Application forms from the Principal, Technical College, Lowfield Street, Dartford. E7125

HER MAJESTY'S COLONIAL SERVICE

COLONIAL ENGINEERING SERVICE

PUPILS AND PROBATIONERS

The Colonial Office announces that a limited number of vacancies exists in the Colonial Engineering Service for PUPILS and PROBATIONERS in Civil Engineering and for PUPILS in Mechanical and Electrical Engineering (including Telecommunications).

The vacancies exist mainly in West, East and Central Africa, Malaya, and the Far East.

Candidates for appointment should hold a Pass in, or, by virtue of a University Degree or other qualification, exemption from Sections A and B of the examinations for Associate Membership of the Institution of Civil Engineers, or the Institution of Mechanical Engineers, or the Institution of Electrical Engineers. Engineering students whose Degree Examinations take place later this year may apply and will, if selected, be offered appointment subject to passing their final examinations.

Applications should reach the Director of Recruitment (Colonial Service), Colonial Office, Sanctuary Buildings, Great Smith Street, S.W.1, in writing, by the 31st of March, 1953, and should give brief details of the candidate's age, qualifications and experience, quoting the Reference CDE/100/011. Further details will be supplied on request. E7080

BRITISH ELECTRICITY AUTHORITY

SOUTH-EASTERN DIVISION

CHIEF GENERATION ENGINEER (OPERATION)

British Electricity Authority (South-Eastern Division) require a CHIEF GENERATION ENGINEER (Operation) at Divisional Headquarters, Kingston-upon-Thames. The commencing salary will be according to qualifications and experience, but will be not less than £1850 p.a., which is provisional pending the negotiation of the permanent salary scale.

Applications, stating age, qualifications, present appointment and salary, to D. Moffat, Director of Establishments, British Electricity House, Winsley Street, London, W.1, by 16th February, 1953. Candidates are asked to submit concise details giving evidence of experience of modern generating plant (mechanical and electrical), organisation and administration, leadership, and knowledge of labour relations machinery. Quote reference AE/318. E7105

PUBLIC APPOINTMENTS

CIVIL SERVICE COMMISSION

SENIOR SCIENTIFIC OFFICERS, SCIENTIFIC OFFICERS, PATENT EXAMINER AND PATENT OFFICER CLASSES

The Civil Service Commissioners invite applications for permanent and pensionable appointments to be filled by competitive interview during 1953. Interviews will continue throughout the year, but a closing date for the receipt of applications earlier than December, 1953, may eventually be announced. The Scientific Posts are in various Government Departments and cover a wide range of scientific research and development in most of the major fields of fundamental and applied science ; in biology the number of vacancies is small. The Patent Posts are in the Patent Office (Board of Trade), Admiralty and Ministry of Supply.

Candidates must have obtained a University Degree with First or Second-Class Honours in an appropriate scientific subject (including engineering) or in mathematics, or an equivalent qualification, or for Scientific Posts possess high professional attainments. Candidates for Senior Scientific Officer Posts must, in addition, have had at least three years' post-graduate or other approved experience. Candidates for Scientific Officer and Patent Posts taking their Degrees in 1953 may be admitted to compete before the result of their Degree examination is known.

Age limits : Senior Scientific Officers, between 26 and 31 ; for Scientific Officers and Patent Classes, between 21 and 28 during 1953 (up to 31 for permanent members of the Experimental Officer class competing as Scientific Officers). London salary scales : Senior Scientific Officers, (men) £812–£1022 ; (women) £681–£917 ; Scientific Officers, (men) £440–£707, (women) £440–£576 ; Patent Examiner and Patent Officer Classes, (men) £440–£655, (women) £440–£576. Somewhat lower rates in the Provinces.

Further particulars from the Civil Service Commission, Scientific Branch, Trinidad House, Old Burlington Street, London, W.1, quoting No. S 53/53 for Senior Scientific Officers and S 52/53, S 128/53 for the other posts. E7098

NATIONAL COAL BOARD

PRODUCTION DEPARTMENT

DRAUGHTSMEN

National Coal Board invite applications for the undermentioned superannuable appointments in the Production Department at London Headquarters.

SENIOR DESIGN and LAYOUT DRAUGHTSMAN, salary range £610 to £860 per annum, plus London location allowance, according to qualifications and experience. Candidates should have first-class experience in connection with modern power stations, including ash and fuel handling equipment. They should have a minimum of Higher National Certificate or equivalent (Ref. No. TT/585).

ENGINEERING DRAUGHTSMAN, salary range £503 to £610 per annum, plus London location allowance, according to qualifications and experience. Candidates should have experience in layout work and general mechanical engineering ; knowledge of power generation equipment would be an advantage (Ref. No. TT/587).

Write, giving full particulars (in chronological order) of age, education, qualifications and experience (with dates), to National Coal Board, Establishments (Personnel), Hobart House, Grosvenor Place, London, S.W.1, marking envelope with the relevant TT reference number quoted above. Closing date 14th February, 1953. Original testimonials should not be forwarded. E7071

HER MAJESTY'S COLONIAL SERVICE

PUBLIC WORKS DEPARTMENT

ENGINEERS

Applications are invited for the following posts :—ENGINEERS.

Vacancies exist for CDE 112/15/02/03 (a) an EXECUTIVE ENGINEER and (b) a ROAD ENGINEER (Temporary), Road Construction Staff, in the Public Works Department in Sierra Leone. Appointment to post (a) is on three-year probation for permanent and pensionable establishment, and to post (b) on contract for one tour of 18 months in first instance. Candidates must hold a recognised University Degree or Diploma in Civil Engineering carrying exemption from Parts A and B of the A.M.I.C.E. examinations, or be Associate Members of the Institution of Civil Engineers.

Full details regarding salaries, allowances, conditions of service, &c., available on application.

Intending candidates should apply in writing to the Director of Recruitment (Colonial Service), Colonial Office, Sanctuary Buildings, Great Smith Street, S.W.1, giving brief details of their age, qualifications and experience. They should mention this paper and quote the reference number (CDE 112/15/02/03). E7081

CRAWLEY NEW TOWN

CRAWLEY DEVELOPMENT CORPORATION

ASSISTANT ENGINEER

The Crawley Development Corporation require an ASSISTANT ENGINEER (Mechanical and Electrical). Salary £630 p.a. by annual increments of £35 and £30 to £850 p.a., with placing according to qualifications and experience. Contributory superannuation. Municipal experience and A.M.I.Mech.E. or A.M.I.E.E. qualification preferred. Application forms from the Chief Engineer, Mr. A. J. W. McIntosh, B.Sc., M.I.C.E., Broadfield, Crawley, Sussex, are returnable by the 14th February, 1953.

C. A. C. TURNER,
E7100 Chief Executive.

PUBLIC APPOINTMENTS

GOLD COAST GOVERNMENT

PUBLIC WORKS DEPARTMENT

EXECUTIVE ENGINEERS (WATER SUPPLY)

Applications are invited for four vacancies in the post of EXECUTIVE ENGINEER (WATER SUPPLY) in the Public Works Department.

Duties : investigation, planning, design and construction of new urban water supplies and extensions to existing supplies varying in capacity from 1 million to 6 million gallons per day, including the supervision of works carried out by direct labour and contract.

Qualifications : candidates should be not less than 30 years of age and should be Corporate Members of the Institution of Civil Engineers and/or of the Institution of Municipal Engineers. They should be experienced in the planning, design and construction of urban water supplies, including the supervision of major construction works.

Terms of service : the appointments will be on contract/gratuity terms for one tour of 18 to 24 months, with a possible extension to two tours. Salary will be in the range £1600–£2020 per annum (consolidated), according to age, qualifications and experience. A gratuity at the rate of £37 10s. for each completed three months of satisfactory service will be payable on final termination of the contract.

Free passages on first appointment and on leave will be provided for the officer and his wife once each way during each tour of service. Officers will normally be required to travel by air. Free air passages will also be provided for a maximum of three children under 13 years of age.

Vacation leave with pay : seven days for each month of service. Free medical and dental attention provided for officer and family. Furnished quarters available at low rental. Income tax at local rates. Kit allowance on first appointment £30–£60, according to salary. Contributions to the Widows' and Orphans' Pension Fund are at present compulsory.

These posts are "development posts" for implementation of specific projects under the Gold Coast Development Plan and are strictly temporary. On termination of the contract, the officer would not be eligible for transfer to any other Government appointment, but would be able to apply for appointment to another post, if desired.

Intending candidates should apply to the Commissioner for the Gold Coast, Melbourne House, Aldwych, London, W.C.2, for an application form. E7090

HER MAJESTY'S COLONIAL SERVICE

GRENADA, WINDWARD ISLANDS

SUPERINTENDENT OF PUBLIC WORKS

Applications are invited for the following post :—SUPERINTENDENT OF PUBLIC WORKS, Grenada, Windward Islands (CDE 112/41/01).

Appointment is on agreement for three years, at a salary ranging from £1200 to £1500 per annum according to the selected candidate's experience and qualifications. Transport allowance of £315 p.a. also payable. Duties would be mainly of an administrative nature. Candidates must be Corporate Members of the Institution of Civil Engineers, and have had administrative experience.

Further details available on application.

Intending candidates should apply in writing to the Director of Recruitment (Colonial Service), Colonial Office, Sanctuary Buildings, Great Smith Street, S.W.1, giving brief details of their age, qualifications and experience. They should mention this paper and quote the reference number (CDE 112/41/01). E7079

CROWN AGENTS FOR THE COLONIES

AGRICULTURAL DEPARTMENT

DEVELOPMENT OFFICER (IRRIGATION)

DEVELOPMENT OFFICER (IRRIGATION), Agricultural Department, required for the Gold Coast Local Civil Service, for one tour of 18 months in the first instance. Salary, according to age and war service, in the scale £940 rising to £1[illegible] a year. Outfit allowance £60. Gratuity at the rate of £100 or £150 a year. Free passages ; liberal leave on full salary. Candidates must have wide practical experience of the organisation and operation of irrigation schemes, including the use of [illegible] machinery in irrigation work.—Apply at once by letter, stating age, full names in block letters, and full particulars of qualifications and experience, mentioning this paper, to the Crown Agents for the Colonies, 4, Millbank, London, S.W.1, quoting letter M.27865 A. The Crown Agents cannot undertake to acknowledge all applications, and will communicate only with applicants selected for further consideration. E7078

MINISTRY OF SUPPLY

WOOLWICH

ENGINEER

Ministry of Supply require ENGINEER at Woolwich, responsible under C.M.E. for operation and maintenance all electrical equipment, including power plant and supply and installation of new plant at Royal Arsenal and Woolwich Dockyard. Qualifications, British of British parentage, recognised engineering apprenticeship, Corp. Mem. Inst. C[illegible] Mech. or Elect. Engrs., or exempting quals. Experience in installation, operation and maintenance in scale electrical plants (generation and distribution A.C./D.C.). Salary, within £1331–£1536. Appointment unestablished, but opportunities may arise for established pensionable posts.—Application forms from M.O.L.N.S., Technical and Scientific Register (K), Almack House, 26, King Street, London, S.W.1, quoting Ref. D.33/53A. Closing date 21st February, 1953. E7[illegible]

THE ENGINEER

JANUARY 30, 1953

The James Watt International Medal

AT a general meeting of the Institution of Mechanical Engineers in London on Friday evening last, January 23rd, the 1953 James Watt International Medal was presented to Sir Harry Ricardo, F.R.S. The presentation was made by Mr. A. Roebuck, vice-president of the Institution, who took the chair at the meeting. Sir Harry, who is the chairman and technical director of Ricardo and Co., Ltd., is a past-president and honorary member of the Institution. The citation accompanying the medal was made by Dr. R. W. Bailey, chairman of the Watt Medal Committee. It said that the medal was awarded to Sir Harry Ricardo in recognition of his contributions to knowledge of the fundamental principles of internal combustion engines and the application of those principles to design and development. Expressing his deep appreciation of the honour which had been bestowed upon him, Sir Harry said that the award of the Watt Medal marked the summit of any mechanical engineer's ambition and rather an epoch in his life. He had thought that the Institution had already bestowed upon him all, and more than all, the recognition that he deserved. It was Professor Hopkinson, Sir Harry continued, who had impressed upon him, nearly fifty years ago, that the future of road transport, then in its infancy, and of aviation, as yet unborn, would lie with the light high-speed internal combustion engine, and Professor Hopkinson had also outlined the probable directions in which its performance could be improved. Professor Hopkinson, too, Sir Harry added, had impressed upon him that the essence of high-speed engine design lay in the combination of a very rigid structure with very light moving parts. He had merely followed up Professor Hopkinson's precepts and lines of thought.

Atomic Power

IN replying to a question in the House of Commons on Monday last, Mr. Duncan Sandys, the Minister of Supply, gave some particulars of the work in progress on the industrial use of atomic energy. He said that the production of electric power from atomic energy raised a number of novel problems which had been studied in the light of experience gained with the graphite piles at Harwell and at Windscale. The most certain method of generating power from atomic energy, he said, would be to build an improved type of natural uranium reactor enclosed in a pressure shell, the heat produced being transferred by a gas under pressure, through a heat exchanger to a conventional electric power generator. As a by-product this would yield plutonium, which could be used as a fuel for further reactors. The potentialities of such a reactor were being actively studied and the Minister stated that if the prospects were shown to be favourable consideration would be given to constructing an experimental atomic power station. It was also hoped to develop "breeder-reactors" and, to facilitate their study, a small experimental reactor of this kind was being built at Harwell. The Minister said that it was not proposed to undertake work on the application of nuclear energy to propulsion until more experience had been gained in the development of stationary power plants, and that it was too early to say how soon electricity generated from atomic energy would be available on a significant scale for industrial purposes. If, as was hoped, the technical problems involved were successfully solved and the new methods proved to be economical, there was no reason why nuclear reactors should not before very long provide a useful additional source of industrial power. Later in the day, when dealing with the Supplementary Estimates, the Minister said that the successful test at Monte Bello had completed an important phase in the programme of atomic research. In connection with work on this sphere of atomic energy, an additional £2,250,000 was being requested for loans for the production of uranium. This was because the process for extracting uranium as a by-product from gold mining had gone ahead in South Africa more rapidly than had been expected, and there had been encouraging developments in Australia which had justified loans to uranium producers.

The "Empress of Canada"

THE Canadian Pacific liner "Empress of Canada," which was originally built as the "Duchess of Richmond" by John Brown and Co., Ltd., in 1928, was seriously damaged by a fire which broke out on Sunday last. The ship, which, together with the "Empress of France" and the "Empress of Scotland," maintains a passenger and cargo service between Liverpool and Canada, had just completed her annual overhaul and had moved to the Gladstone Dock to load cargo in readiness for her next sailing to Canada. The fire was discovered on one of the lower decks during the afternoon and quickly spread to the decks amidships, and in spite of the efforts of a large number of firemen and engines aided by the Mersey Docks and Harbour Board vessel "Salvor," the fire continued to gain ground until it appeared that the whole of the superstructure was blazing. As the fire spread explosions occurred in the ship and the amount of water pumped on board caused the ship to develop a dangerous list towards the quay and the firemen had to be withdrawn. Hoses continued to play on the side of the ship and efforts were concentrated upon saving the sheds on the quay and removing nearby ships to safe berths. Scuttling the ship or lowering the level of the water in dock to allow the vessel to rest on the bottom was discussed and at a late hour it was reported that the ship must be considered as a total loss.

William Froude Memorial

AT the Sixth International Conference of Tank Superintendents, held in Washington in 1951, a suggestion was put forward for a William Froude Memorial. As a result of this, the Council of the Institution of Naval Architects has been considering a proposal to commemorate in a suitable manner the pioneer work of William Froude, to whose original experiments in ship model research, shipbuilders and shipowners throughout the world are indebted. The Council announces that it is willing to support such an undertaking and proposes that the memorial should consist of the erection of a bronze plaque and the publication of a volume containing William Froude's published technical papers. It is proposed to erect the plaque adjacent to the site of William Froude's original experiment tank at Torquay, South Devon, the nearest point being a country lane where a space could be cleared for a stone wall background into which the plaque would be set. To cover the cost of both proposals a sum of £2500 is required and the Council believes that other organisations connected with the industry, in this and other maritime nations, will wish to be associated with the proposal; as sponsor, it issues an appeal for contributions to the memorial fund. It is planned to send to each subscriber a complimentary copy of the publication, which will contain a preface with subscribers' names, a short biography and papers. The bronze plaque will be inscribed as follows: "William Froude, F.R.S., LL.D., 1810–1879—William Froude was born in 1810 at Dartington, Devon, and lived at Chelston Cross from 1867 until his death in 1879. His outstanding contributions to the science of naval architecture brought him world-wide renown. He was the pioneer of ship model research and in 1872 built the first experiment tank in the world on this site for the Admiralty, for whom his main work was carried out. This memorial was erected in 1954 by Naval architects of many countries as a grateful tribute to his memory and genius."

Administrative Costs of Gas and Electricity Boards

THE Association of British Chambers of Commerce has sent a memorandum to Lord Leathers, Secretary of State for the Co-ordination of Transport, Fuel and Power, urging the Government to encourage administrative co-ordination between gas and electricity undertakings as a means of reducing costs. The Association points out in this memorandum that, in the year 1950–51, of the total operating costs of the British Electricity Authority, amounting to £209,000,000, nearly £18,500,000, or over 9 per cent, was spent on purely administrative services in connection with distribution. Comparable costs were also incurred by the Area Gas Boards. The principal recommendation made in the Association's memorandum is that a group of experts drawn from industry and commerce, as well as from the electricity and gas undertakings, should be appointed to examine the problem in all its aspects. If in each area, the memorandum says, the gas and electricity undertakings could agree to the pooling in the first instance of certain limited administrative functions such as meter-reading and collection and accounts, it might well follow that some joint use of transport, premises and other services could also be arranged. The staff required to serve such an administrative pool would presumably show a reduction when compared with the numbers at present engaged in those functions in the two undertakings. The Association emphasises that its recommendations refer only to the administration of the undertakings; it is not the intention that there should be any integration of operational functions or stifling of the spirit of competition between gas and electricity. It should be added that Lord Leathers has informed the Association of British Chambers of Commerce that the question of administrative costs in gas and electricity undertakings is receiving consideration.

Guided Rockets

IN the course of his statement when the Supplementary Estimates were presented to Parliament on Monday last, Mr. Duncan Sandys, the Minister of Supply, said that in the main the increased expenditure provided gratifying evidence that the progress of the technical and scientific establishments of the Ministry and of the industries working with it had been more rapid than had been anticipated a year ago. In concentrating expenditure on the points which mattered most a special effort had been made to accelerate development of new types of airframes, aero-engines, electronic equipment, and improved methods of jet propulsion. Work on guided rockets had been intensified and encouraging progress had been achieved. In pointing out that there could be no doubt that the guided rocket would be one of the decisive instruments of war in the not-too-distant future, the Minister said that weapons travelling at several times the speed of sound were being successfully evolved for use in both defensive and offensive roles. It was considered that, wherever else retrenchment might be acceptable, work on guided rockets must be allowed to forge ahead, and that to hold back, in any way, scientists and technicians working in this vital field would be false and dangerous economy.

Sewage-Sludge Digestion Calculations

By L. B. ESCRITT

No. I—QUANTITY OF SLUDGE AND TANK CAPACITY

For those who like precise and elaborate sewage-works calculations, the design of digestion plant must be, in part, a disappointment, for, apart from the details of the mechanical plant, the calculations are unavoidably based on very wide assumptions. Any engineer can, of course, make detailed calculations of quantities of sludge and availability of, and demands on, heat, but he should be aware that the answers he gets are not necessarily as accurate as those obtained by such of his brethren as prefer to save time by using accepted rules-of-thumb. Here the whole subject is discussed and illuminated by specimen calculations.

THERE are considerable differences in conditions at sewage-treatment works, and in sludge digestion plant many factors, including the scale of the installation, influence performance. Estimates, therefore, of tank capacities, detention periods, and heat demands and losses are necessary for the purpose of deciding on the kind of installation or on important details such as the necessity for heat insulation.

Importance of Estimated Quantity

The importance of estimation of quantity of sludge is that on this depends the capacity of the digestion tanks, particularly the primary tank from which it is seldom practicable to remove supernatant water. If this tank is too large, too much money will have been spent : if it is too small, gas production may be reduced by a little, or perhaps foaming may result.

Correct estimation of sludge quantity is also important from the point of view of heating, for the estimate of heat demands and the design of the heating installation have to be based on the maximum quantity of sludge expected. There may perhaps be little harm in over-designing heating plant for a small installation, but it would matter in the case of large works.

Quantity of sludge must depend on the amount of solid matter delivered to the works in the sewage. The difficulty, however, in estimating quantity of sludge is that the moisture content is very variable and cannot be predicted other than very approximately. Accurate moisture content quantities can, in fact, be determined only when samples can be collected from existing sedimentation tanks : in all other circumstances guesses have to be made.

Where new sedimentation tanks will be constructed but it is possible to sample the sewage, the quantity of sludge can be estimated by finding the number of gallons of dry matter which, according to analyses and flow records, should be delivered to the works, and assuming the addition of a moisture content to this dry matter. If, however, the proposal for sewage-treatment is entirely new, sludge quantity must be estimated on the assumption of similar conditions to those at works previously constructed elsewhere.

Example Calculation

For the purpose of illustrating the methods of estimating sludge quantity, we will assume that sludge digestion has to be provided at sewage-treatment works where the conditions are as follows :—

Population	50,000
Average daily flow	2,000,000 gallons
Suspended solids content	250 parts per million
B.O.D. value	300 parts per million
Required standard of treatment	Royal Commission effluent
Proposed method of sewage-treatment	Activated sludge

The first calculation relating to sludge quantity that can be made from the above figures is that, as the flow is 2,000,000 gallons per day and the suspended solids content 250 parts per million, the quantity of solids being delivered to the works must be 500 gallons in terms of dry matter. All this must go to form the solids content of sludge except the small quantity of suspended matter which escapes with the treated effluent and an undeterminable small quantity which may be lost by liquefaction before the sludge leaves the sedimentation tanks. As the maximum quantity of suspended solids permitted in a Royal Commission effluent is 30 parts per million and the actual quantity at good works usually averages considerably less, the dry solids lost via the outfall can generally be neglected in the sludge calculation.

On the other hand, the processes of sewage treatment involve the growth of organisms and consequent production of organic solids, partly by utilisation of the dissolved solids content of the sewage. Thus, there should be more sludge produced than comes down the sewer. In the case of percolating filter schemes, no allowance is made for such new suspended matter ; but in activated sludge schemes the quantity is appreciable and allowance should be made for it. One figure that has been suggested for estimating this " new organic matter " (which should not be confused with what is known as " surplus sludge "), is to allow 0·2 lb of new dry matter per pound B.O.D. treated.

Thus, on the basis of the above data :—

$$\text{Pounds B.O.D. per day} = 300 \times 2 \times 10 = 6000.$$

$$\text{Pounds new suspended solids} = 6000 \times 0{\cdot}2 = 1200, \text{ or 120 gallons.}$$

Therefore quantity of dry matter forming sludge is :—

	Gallons per day
Suspended solids in sewage	500
Solids produced by activated sludge process	120
Total suspended solids	620

Effect of Moisture Content

Figures of sludge moisture content that have often been assumed are 97½ per cent for primary sludge removed from pyramidal-bottomed sedimentation tanks, and 95 per cent for primary sludge from flat-bottomed swept tanks. The high moisture content of sludge from pyramidal tanks is due to the difficulty of withdrawing sludge under hydrostatic head without also drawing off some sewage, and also to the lack of consolidation such as that which, in flat-bottom tanks, results from sweeping.

If a moisture content of 97½ per cent is assumed, the quantity of sludge in our calculation will be :—

$$\frac{620 \times 100}{100 - 97\frac{1}{2}} = 24{,}800 \text{ gallons per day.}$$

If, on the other hand, the moisture content is taken as being 95 per cent, sludge quantity will be :—

$$\frac{620 \times 100}{100 - 95} = 12{,}400 \text{ gallons per day, or only one-half the above quantity.}$$

This calculation demonstrates a fact that usually surprises young engineers the first time they do sludge calculations—i.e. an apparently small difference of moisture content produces a very great difference in the quantity of sludge to be handled—and shows how important is accurate estimation of moisture content.

It is obvious that it is here that some compromise has to be made between extreme figures. A 95 per cent moisture content is not unlikely if the tanks are mechanically raked. But you cannot be sure of it, and so had better allow 96 per cent. The quantity of sludge then becomes :—

$$\frac{620 \times 100}{100 - 96} = 15{,}500 \text{ gallons per day.}$$

If you have pyramidal tanks you will probably draw off sludge with a moisture content in the region of 97½ per cent, in which case you should consider dewatering, or else you will be compelled to put in extravagantly large digestion tanks.

The only normal means of reducing moisture content of sludge after the sludge has been withdrawn from sedimentation tanks, and before it is put into digestion tanks, is the removal of supernatant water that collects if the sludge is stored in quiescent conditions in dewatering tanks. Another process which has been tried is dewatering by mechanical flocculation, but this method has, in most instances, proved difficult to control, for although water bands have been produced they have not always occurred where expected and therefore could not always be drawn off.

The use of quiescent dewatering tanks is also rather controversial, but the method certainly works and such tanks are a normal adjunct to one kind of sludge digestion installation. They should not be necessary when the sludge is initially dense. But without them a wet sludge is a problem. They usually take the form of simple, deep tanks, to which crude primary sludge is pumped or gravitated. A total capacity of twenty-four hours' sludge production (on the basis of initial moisture content) has been recommended and it is thought that this should be in not fewer than two, and preferably in four, individual tanks. Decanting valves are provided for the stage-by-stage withdrawal of supernatant water. The sludge, after detention for several hours, during which as much supernatant water as possible has been removed, is pumped to the digestion tanks.

Changes of sludge quantity can be calculated by Santo Crimp's formula, which reads as follows :—

$$W_2 = \left(\frac{100 - P}{100 - Q}\right) W_1$$

where :—

W_1 = Original weight of sludge
W_2 = Weight of dewatered sludge.
P = Per cent moisture of sludge before dewatering.
Q = Per cent moisture of dewatered sludge.

Rule-of-Thumb Figures

Before leaving the subject of quantity of sludge, mention should be made of the rule-of-thumb figures to be used when there are no data available because no works or sewage exist at the time that the calculations are made. The following figures have been used : one-quarter gallon per head per day at 95 per cent moisture content for sludge from swept tanks, and one-half gallon per day at 97½ per cent moisture content, for sludge removed under hydrostatic head from pyramidal tanks. On the basis of this rule, and the above formula, the quantity of sludge at 96 per cent moisture content would be 0·312 gallons per head per day. This can be

compared with the quantity calculated in the more detailed calculation, which was 15,500 gallons per day from a population of 50,000 persons, or 0·31 gallons per head per day.

Tank Capacity

Capacity of digestion tank depends on the volume of sludge delivered to digestion per day and the required detention period in days. The detention period required varies with the temperature of sludge during digestion and the amenability of the sludge to digestion.

There are three types of sludge digestion : "cold" digestion at normal sewage temperatures ; "mesophilic" digestion, in which the sludge is moderately heated, and "thermophilic" digestion, in which the sludge is heated to a greater extent.

As to cold digestion, more or less accepted figures are that an economic degree of digestion is effected when domestic sludge not containing inhibitory trade wastes is detained for 108 days at 50 deg. Fah., or eighty-five days at 60 deg. Fah. Figures in the mesophilic range are forty-seven days at 70 deg. Fah., thirty-eight days at 80 deg. Fah., thirty days at 86 deg. Fah. (the usual design figure), and twenty-seven days at 90 deg. Fah. In thermophilic digestion, detention periods can be reduced to about seventeen days on temperature being raised to 110 deg. Fah. or 120 deg. Fah., but this method is little used because it is not very easy to operate.

The calculation of detention period is complicated by the fact that, during some stage or stages of detention, supernatant water can be drawn off, reducing the moisture content and volume of the sludge and thereby lengthening the detention period for any given size of tank.

Most modern sludge digestion is in two stages, there being primary and secondary tanks, this applying regardless of whether or not the sludge is heated. Thus, cold sludge can be delivered to primary digestion and then to secondary digestion ; or sludge can be digested at a high temperature in primary tanks and then passed to secondary tanks, where the temperature is maintained by continued heating or else allowed to fall off to some extent as a result of radiation losses.

Owing to the complexity of the calculation of sludge quantity and detention period when allowance is made for the variability of solids in sewage, the great variability of the initial moisture content and the variable amount of supernatant water that can be withdrawn during digestion, rule-of-thumb figures for tank capacity are used either for design purposes or as a check on calculations of a more intricate nature. These figures are more or less as tabulated here :—

Rule of Thumb Figures for Tank Capacity

Type of Treatment	Cubic feet capacity per head of population	
	Domestic sewage	Sewage containing trade waste
Single-stage digestion at day temperature	3 to 4	6 to 8
Single-stage digestion at 85 deg. Fah.	1½ to 2	4 to 5
Capacity of primary tank of two-stage digestion at day temperature	2 to 2½	3
Capacity of secondary tank of two-stage digestion at day temperature	1 to 1½	3
Capacity of primary tank of two-stage digestion at 85 deg. Fah.	¾ to 1	2 to 2½
Capacity of secondary tank of two-stage digestion at 85 deg. Fah.	¾ to 1	2 to 2½

A Mesophilic Scheme

For the purposes of the present calculation we will assume that it has been decided to install mesophilic digestion with one primary and one secondary tank. The primary tank will be heated to a temperature which will not fall below 86 deg. Fah. during the winter, when sewage temperature is 45 deg. Fah. and air temperature 35 deg. Fah. The secondary tank will benefit by the heat in the sludge as delivered to it but will not otherwise be heated. It will be considered impracticable to withdraw supernatant water from the primary tank owing to turbulence intentionally produced to ensure mixing and also resulting from emission of gas. It will be assumed that the secondary tank will benefit from withdrawal of supernatant water and that the increased detention period resulting from this will more or less balance out the increased detention period necessitated by reduction of temperature by radiation.

If both tanks were heated and there were no removal of supernatant water, the overall detention period would have to be thirty days, or fifteen days per tank. In the calculation in the previous article the quantity of sludge was 15,500 gallons per day at 96 per cent moisture content and this was produced by a population of 50,000 persons. Thirty days' storage of this quantity would be 465,000 gallons, or 74,400 cubic feet. This is slightly less than 1½ cubic feet per head of population or the rule-of-thumb figure given in the foregoing table, and as the last is about the minimum normally allowed it would not be unreasonable to substitute it for the calculated figure.

We thus arrive at a capacity of 75,000 cubic feet equally divided between two tanks : the next step is to determine the proportions and main details of the primary tank. In this connection the matter of gas collection has to be considered, for at small works and not infrequently at those of larger scale, gas can be most conveniently stored in spiral gasholders constructed over circular digestion tanks. By far the greater proportion of the gas available is given off by the sludge in the primary tank and, therefore, unless all the gas is required for the production of power or heat, it might in some circumstances be unnecessary to provide a holder or gas-proof roof for the secondary tank.

However, to allow for maintenance and inspection and for the possibility of (for this or other causes) the primary tank or gasholder being out of commission, it is desirable for there to be another tank which can serve as primary, and another gasholder. The simplest arrangement, in the present instance, is to design both tanks alike, provide both with gasholders and to arrange the pipework in such a manner that either one or the other can serve as primary tank ; or, if found advantageous, the two tanks may be run in parallel.

This involves some problems, for in addition to somewhat complicated pipework, it means that, with certain kinds of heating installation such as internal heating coils, both tanks would have to be heated : it also makes desirable the provision of supernatant liquor decanting arrangements for both tanks.

Gasholder Capacity

It is not easy to say what is the exact gasholder capacity required in any particular instance, because, again, there are many variables. Theoretically it might be possible to arrange for sludge to be delivered at a steady rate of flow throughout the twenty-four hours and thereby ensure a constant rate of gas production. Then, if utilisation of gas were at a constant rate, or at all times at a lower rate than the rate of production, gasholder capacity would be theoretically unnecessary.

But in practice gasholders are always desirable ; and as constant delivery of sludge to digestion is possible only at large works where there are night shifts employed, and then only if dewatering or other balancing tanks are provided, it is more usual to assume that sludge is delivered in a short period of time not exceeding six hours during the working day. Such dosing of the tanks makes rate of gas production irregular and calculations based on experimental results suggest that, if all the gas is to be utilised and at a more or less constant rate, the gasholder capacity normally available should be between four and five hours production. This figure is not infrequently assumed.

To obtain a close estimate of the amount of gas storage theoretically required to balance irregularities of production and utilisation throughout the day, a curve of cumulative or total production of gas against time should be plotted, and a similar curve of total utilisation over the twenty-four hours. In both cases quantity of gas should be plotted as ordinates and time as abscissae. Then, from the peak point (or point of maximum convexity) on the gas production curve a line should be drawn at constant height above the demand curve, when the maximum vertical measurement between this line and the production curve will represent the minimum storage required.

It is not practicable to allow sufficient storage to provide for the prolonged variations of gas production which are caused by storm flows. The rate may vary 20 per cent above or below the average for a few days, or 10 per cent for as long as a week, according to local conditions. Such variations mean the burning to waste of surplus gas and, in the case of shortage, use of alternative heat or power.

We will assume in this instance a five-hour gasholder capacity, or 2½ hours' gas production in each gasholder. The quantity of gas produced varies, according to local conditions, between the limits of about 0·6 and 1·2 cubic feet per head of population per day. In the absence of local knowledge a figure of 0·8 is most frequently adopted for design purposes. On this basis the capacity of one gasholder will be :—

$$\frac{50{,}000 \times 0{\cdot}8 \times 2\frac{1}{2}}{24}$$

$$= 4170 \text{ cubic feet.}$$

Proportions of Tank and Gasholder

Having determined the capacity, the designer must next decide on the depth of the primary tank. This can be varied between limits and normally is not less than 20ft or more than 30ft. Too deep a tank results in, or at least encourages, foaming, and this is particularly the case if the primary tank is of low detention period. Foaming is the result of a high rate of ebullition of gas per unit surface area. Too shallow a tank is uneconomical from the point of view of construction : it also results in increased radiation losses. A shallow depth means that, if the tank is covered by a gasholder, the diameter of the gasholder is increased, adding to both costs and radiation losses.

Emission of gas in excess of 30 cubic feet per day per foot super of sludge surface is considered excessive and liable to cause

foaming. Design should be well inside this figure.

For these reasons very small circular tanks are made of depth equal to diameter, provided that this does not result in a depth of more than 30ft.

For the purposes of the present calculation, we will assume that to suit the conditions of the site, including the maximum height of structures for the sake of appearance, the tank is 25ft deep and therefore the surface area is $\frac{75{,}000}{2} \times \frac{1}{25} = 1500$ superficial feet and the diameter 43ft 9in.

The gasholder will, unless the tank is unusually shaped, have a diameter of about 1ft less than the tank and in this case this will be 42ft 9in, giving a superficial area of 1440 superficial feet. Therefore to hold 4170 cubic feet the working depth of the gasholder would have to be approximately 3ft.

(To be continued)

Welding in Marine Engineering

By H. N. PEMBERTON, M.I.Mech.E.*

No. II—(*Concluded from page 133, January 23rd*)

The twenty-fifth Thomas Lowe Gray Lecture, which was read before the Institution of Mechanical Engineers on January 9th, and of which we publish an abstract, surveys and comments on the use of welding for the construction and repair of marine machinery. This history of welding is traced, various applications are grouped in a section entitled "New Construction," and several examples of weld repairs are described.

Machinery Components

THE use of welding for diesel engine bed-plates and entablatures received an impetus during the 1939–45 war, when under-water explosions were effecting serious damage to cast iron engine bed-plates.

There are two interdependent advantages claimed for welded engine bed-plates and entablatures; these are freedom in design and saving in weight. Larger and more conveniently arranged crankcases can be obtained, which facilitate overhaul, and also scavenge and exhaust belts, camshaft brackets and crosshead guides can readily be incorporated in the fabricated design. In a welded engine entablature the upward vertical loads may be transmitted to the bed-plate through the steel structure instead of by the long "through bolts" used in cast iron engines.

A welded engine bed-plate requires two fore-and-aft girders with a number of transverse beams slung between them to house the main bearings in which the crankshaft is bedded. The loads on the girders and transverse beams are readily calculable and working stresses are negligible, since rigidity is essential and deflection must be restricted to a minimum.

This use of plates of mild steel instead of cast iron results in a saving in weight of between 20 and 30 per cent. In a particular instance, that of a large marine oil engine of the "Gotaverken" type, designed to develop 750 b.h.p. per cylinder, the welded design effects a saving in weight of 37½ lb per brake horsepower.

The extreme simplicity in the design of bed-plate can be seen in Fig. 10.

An example of British practice in engine fabricated structures is that of the "Doxford" oil engine, typical constructional details can be appreciated from the column unit shown in the illustration herewith Fig. 11.

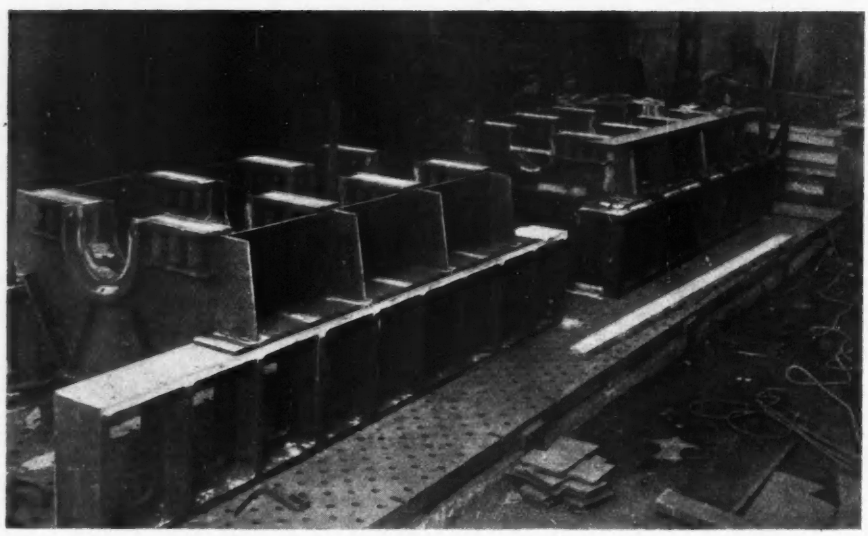

Fig. 10—Sections of a Fabricated Bed-Plate

Welded engine bed-plates, columns and entablatures have been in marine service for a considerable time and it can be stated that this construction has proved to be completely reliable.

During recent years welding has been adopted for the construction of the low-pressure turbine casing of marine installation. Since these turbines exhaust direct to an underslung condenser, the outer casing is a box which can be readily fabricated; the blade carriers are also fabricated and supported on the casing.

Serious technical problems arise in the application of welding in the construction of high pressure and temperature marine steam turbines and they are accentuated in gas turbines. Welding research authorities would do well to give prior attention to problems of high temperature operation, since welding technique and electrodes must be suitable not only to weld the alloy steels but also to provide weld metal capable of service performance equal to that of the parent metal. There are ferritic steels suitable for elevated temperatures, some of which may be classed as weldable, namely, those containing 0·12 per cent carbon and 0·5 per cent molybdenum, with or without the addition of chromium or vanadium.

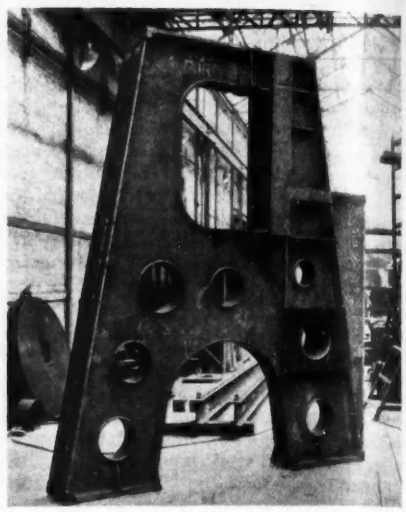

Fig. 11—Column Unit

The main problem in welding these ferritic steels is the tendency to crack in the fusion zone of the weld and with carbon-molybdenum steel graphitisation in the fusion zone has proved to be a serious defect in welded steam pipes in the United States. Some manufacturers employ both preheating and stress relieving, others stress relieve only, but the employment of either of these processes depends on the nature and size of the component. The electrode normally used for welding these steels is designed to give room temperature properties similar to those of the steel, but lacking information on the long-term behaviour of the weld metal under elevated temperatures, this basis for electrode selection may prove misleading. In gas turbines there is the added complication of the effects of high temperature oxidisation and sulphurous gases on the weld metal.

Special steels have been developed to give improved heat and oxidation resistance, but are at present not weldable. The primary purpose of the steelmaker must be to produce a steel to give the required long-term performance under a variety of arduous service conditions, and it is by welding research that means must be devised for welding these steels.

The gas turbine brings its own welding problems. Difficulty in producing austenitic steel forgings of the required sizes necessitates the fabrication of large turbine rotors by welding together a number of forgings. In high temperature steam turbines certain manufacturers have fabricated the rotors from forged steel discs welded together round the periphery.

As an example of welded construction applied to a steam turbine rotor shaft, Fig. 12 shows an assembled rotor, machine finished.

In marine turbine installations it is not

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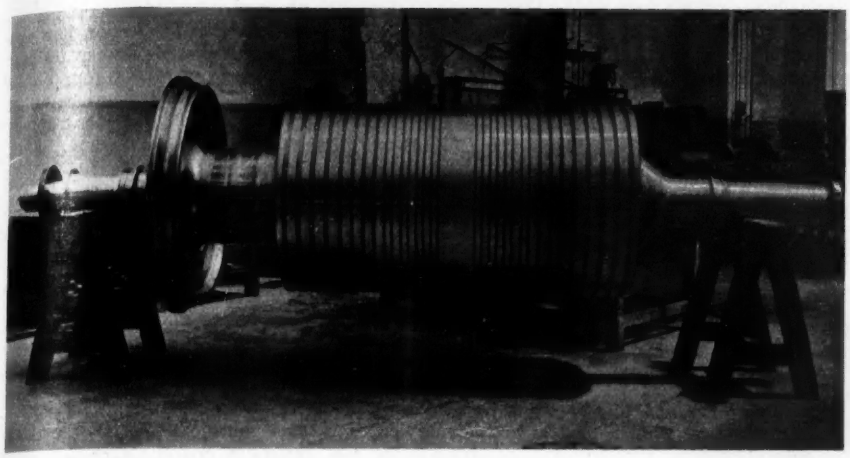


Fig. 12—Assembled Rotor

uncommon for the main gear wheels to be of welded construction. The centre hub is usually a mild steel forging and the radial discs are made from rolled steel plates. The rim in which the gear teeth are cut may be of alloy steel and this gives rise to some difficulty in welding it to the discs, to avoid cracking in the fusion zone. The problem is to provide a sufficient degree of flexibility when the alloy steel rim is being welded to the radial discs. Fig. 13 shows a fabricated gear wheel 8ft 2in in diameter, in which a carbon steel rim is welded to mild steel radial plates. It will be noted that slots are cut between the periphery of the radial plates and the lightening holes, to provide some degree of flexibility during welding.

It is common practice now to fabricate gearcases from welded mild steel plate. As with oil engine bed-plates, rigidity is an essential factor in design. Bearings housings may be either forgings, castings, or made from heavy rolled steel plate and incorporated in the weldment. Flat plate panels forming the sides and ends of the gearcase are stiffened against vibration. A possible objection to the welded gearcase is that it is

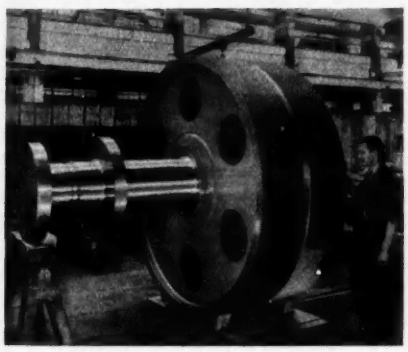


Fig. 13—Fabricated Main Gear Wheel

apt to act as a sound-amplifying box, thus accentuating gear noise, which would be more effectively damped in a cast iron gearcase.

Other Machinery Details

Apart from gear wheels and turbine and electric rotors, welding is infrequently used for the construction of moving parts of marine machinery. In isolated cases crankshafts, connecting and eccentric rods, crossheads and pistons have been fabricated with varying degrees of success and the building of auxiliary-engine crankshafts by welding together a series of drop-forgings has been mooted.

A special application of welding which is of interest is the construction of a lightweight marine propeller (Fig. 14), fabricated from steel castings and plates. This has possibilities in offering a ready means for adjusting weight disposition in design, and also in facilitating the incorporation of corrosion and erosion-resisting material for the blade faces. It is, however, a very unusual type of propeller.

Another uncommon and interesting example of welding is the construction of a piston for the low-pressure cylinder of a steam reciprocating engine (Fig. 15). This special construction was adopted with a view to reducing the reciprocating weights and hence the inertia forces.

In marine refrigerating plant, fusion welding is used almost exclusively in the manufacture of pressure vessels, although in the smaller sizes the shells are generally made from solid drawn or forged lap-welded tubing. The design of the vessels follows orthodox lines, but a usual feature of condensers and evaporators is the tube plate, which is considerably thicker than the shell—the object being to obtain tube tightness when the tubes are held by expansion into grooves. In some cases, however, thinner tube plates, with the tubes secured by welding, have been adopted. A start was made recently in the use of butt-welded, intermediate joints in a marine carbon dioxide piping system instead of the usual flanged joints, and the butt-welded joints showed obvious advantages over the flanged joints when it came to fitting the insulation.

A special field of marine engineering in which welding now plays a major part is in the building of dredgers. Modern methods of building the hull involve the prefabrication of a number of hull units, which are assembled and welded together on the building berth. Superstructure and bucket ladder are also prefabricated.

Special mention should be made of an important welding application to dredging equipment, namely, the deposition of hard surfacing on the faces of the upper and lower tumblers that drive the bucket chain, and also on the digging edges of dredge bucket lips. The tumblers are subject to heavy impact loading and severe abrasion, and the area of hard surfacing, for which special welding

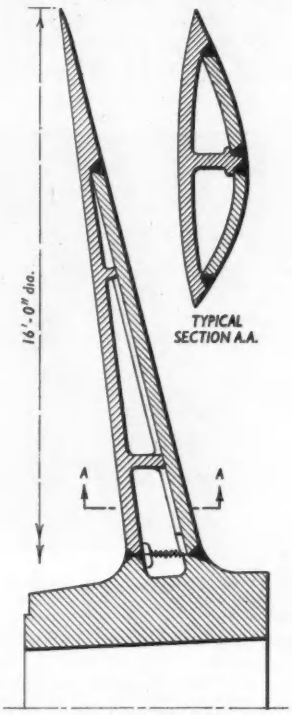


Fig. 14—Fabricated Marine Propeller

electrodes are necessary, is usually restricted to the width of the bucket links and to the area of the bucket base in contact with each tumbler. Instead of fitting renewable lips to dredge buckets, modern practice is to weld a layer of hard surfacing along the cutting edge. This edge is subject to extensive wear, but an advantage of welding is that the hard surfacing can be renewed, as required, without dismantling the dredge equipment.

Upper and lower tumblers are shown in Fig. 16.

General Remarks on New Construction

It will be of some interest to mention the subject of stress relieving of welded joints,

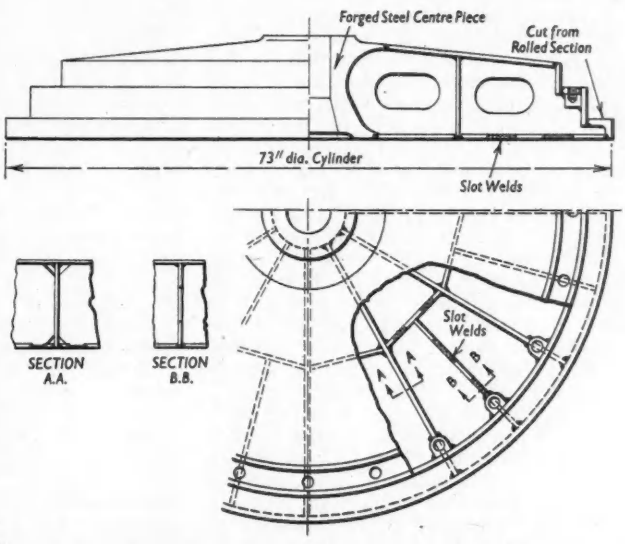


Fig. 15—Fabricated Piston for Steam Reciprocating Engine

since there is some divergence of opinion regarding the importance of this operation.

Research has been carried out to determine the effect of residual stresses induced by welding, but no positive results have been obtained to prove that these residual stresses are harmful to the serviceability of the welded joint. The more severe the degree of restraint during welding, the higher are the resultant strains, transversely and longitudinally to the weld. Welding stresses arise in a manner similar to that of any other residual stress which is introduced into material that has been worked. They are due to plastic deformations in the welding metal and the components of the joint. The stress system induced by these deformations is self-balancing, and therefore it is erroneous to regard residual stress as additive to the stresses induced by external loading. If they are additive in one position they must necessarily be subtractive in another, and the collapse load will remain unaffected.

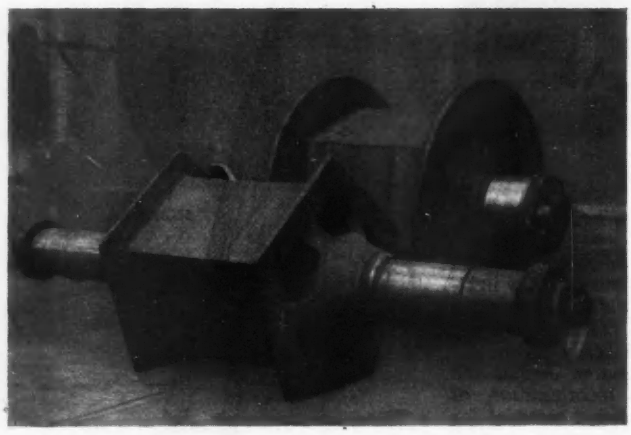


Fig. 16—Upper and Lower Chain Tumblers of Bucket Dredger

In addition to the stresses induced by plastic deformations, stresses may also result from the volume changes which accompany phase changes when metal is heated or cooled through the critical temperatures. If brittle constituents are formed, cracking may occur. Cracking may also occur if yield is inhibited by restraining forces. Yield inhibitors of various degrees of severity are : a system of bi-axial or tri-axial loading ; a notch, which may be a hair crack, slag inclusion or non-penetration in the weld; and low temperatures.

It has been proved by strain measurements that the magnitude of residual welding stresses may approach the yield point of the material. Therefore, the inhibition of yield might well induce a crack which will occur in a direction transverse to the stress responsible for it. Brittle fractures in ductile metals occur through the inhibition of yield.

It is unlikely that a fusion arc weld free from notches can be produced as a normal commercial production, so the elimination or reduction of residual stress by stress relieving treatment is desirable. If in service the weldment is likely to be subjected to the further yield inhibiting condition of low temperature, then stress relieving becomes even more desirable. The need for what is sometimes termed " machining stability " is another reason for stress relieving weldments. Where a system of residual stresses exist, the removal of metal by machining results in a redistribution of strain, and this may cause distortion which might seriously affect the dimensions of the weldment as machining proceeds. Thermal stress relieving will minimise the tendency to distort, but where stress relieving cannot be carried out, distortion must be allowed for by providing sufficient excess metal in the parts which are subsequently to be machined.

Repair Work

Unlike land plant, for which complete resources for repairs are always available, marine machinery may be involved in mishaps and breakdown on the high seas and in remote parts of the world, and many ships now carry electric welding equipment.

In connection with boiler repairs, several instances have been noted where, in double-ended boilers, at the intermediate circumferential riveted seams, the edge of the middle strake of shell plating had, at some time during service, been indiscriminately sealed with heavy fillet welds, resulting in an extensive circumferential cracking. These were subsequently repaired by removing the heavy fillets, welding up the cracks and sealing the plate edges with a light fillet weld.

Cracks in combustion chambers and furnace flanges in way of rivet holes are commonly repaired by welding. Where, however, these cracks are caused by caustic conditions, it is unwise to attempt repairs before making a very complete examination of all riveted seams.

In view of the urgent necessities of war, welding has been used to carry out permanent repairs of main screw shafts under carefully controlled conditions, and is accepted by some authorities at the present time.

The crankshaft journal, 17¼in in diameter, for a Doxford main engine was found to be cracked in way of a side crank pin and the adjacent outer web, and a repair was made. A ring was first mounted over the side crank pin and mild steel shaped blocks were fitted between the outer and inner webs, the entire arrangement then being heavily block welded and finally secured by means of two stud bolts of 4in diameter. On completion of this repair the ship made a successful voyage from New Zealand to Britain.

Another very interesting example of a successful temporary repair to a crank web by welding is that of a main engine crankshaft. A strap of heavy section (11in by 4in) was laid in place along the crank web, secured at one end, and heated by a system of electric elements until its extension equalled the width of the crack when final welding began. The additional heat generated during welding produced a further slight extension, and when the assembly cooled down on completion of the welding the crack was effectively closed.

As a further example of the use of welding, a repair was carried out on a main engine crankshaft of the semi-built type. The crank pin had completely fractured. Not unnaturally, the owners desired the least possible delay and, since a solid forged distance piece could not be obtained in the time available, a " bobbin " make-up piece was fabricated from a piece of scrap shaft and heavy boiler plate. This repair was carried out in a well-equipped shore establishment, where the piece was annealed and the welding inspected by "Magna Flux" tests.

A further interesting application has been to make good the effects of wear on gear wheel shafts. A gear wheel was found to be slack on its hub ; the fitting surface of the shaft was built up by welding under carefully controlled conditions and, on completion, the shaft was stress relieved in a non-oxidising furnace.

So much has been said of the many advantages of welding that it is perhaps prudent to draw attention to the indiscriminate or ill-advised use of welding which, by virtue of its ease of application, is apt to be abused. The application of welding sets up high, local residual stresses, particularly where relatively small deposits are laid on a larger mass of metal, and these may give rise to incipient cracking in the weld deposit. There is also the possibility of blowholes and slag inclusions, which may act as stress raisers. The influence of welds in engine forgings subject to dynamic loads requires investigation, and, in the light of present knowledge and experience, such welding cannot be generally accepted.

Just as welding is a legitimate method of construction when used under proper control and supervision, so it may be applied in effecting permanent repairs under similar conditions. The secret of good welding is good preparation of the parts to be welded. Root gaps, depth of root faces, shape of weld grooves, and the close abutment of components to be welded, are factors in welding of equal importance to quality of electrode and correct welding technique.

The advantages of radiographic examination as a control of weld quality cannot be too strongly emphasised, and in new construction many manufacturers have found this to be the best means for maintaining a good standard of workmanship.

A Plastic Mouldable Refractory

A new addition to the range of refractories made by the Morgan Crucible Company, Ltd., Battersea Church Road, London, S.W.11, is the " M.R." plastic mouldable refractory for service at high temperatures or where severe spalling or slagging is encountered in industrial furnaces. It is designed for a maximum operating temperature of 1650 deg. Cent. and can be used to advantage where high duty refractory bricks are normally employed. The material can readily be moulded *in situ* to replace special shapes in a furnace and it eliminates the need for cutting and fitting.

The plastic is supplied in air-tight drums containing 1 cwt or about seven-tenths of a cubic foot. To apply it, the surface on which it is required is cleaned and wetted and then slugs of the plastic are pounded firmly into position with a hammer or mallet. The plastic is applied in a series of layers each being pounded firmly on to the previous layer, until the required shape is built up to form a lining, patch or capping, &c. If necessary, formers can be used to give the required shape and it is pointed out by the makers that the material cannot be " over-rammed " so that comparatively unskilled labour can be used for its application.

The approximate analysis of the plastic is given as alumina 60 per cent, silica 36 per cent, ferric oxide 1·3 per cent and alkalis 1 per cent. With its limiting operating temperature of 1650 deg. Cent. the material has a P.C.E. Seger cone 33/34, and its shrinkage from setting to drying is stated to be not greater than 0·75 per cent. From dry to one hour at 1620 deg. Cent. the shrinkage is claimed to be not greater than 1 per cent. The modulus of rupture after firing for one hour at 1000 deg. Cent. is approximately 200 lb per square inch and 750 lb per square inch after firing one hour at 1620 deg. Cent. As moulded the plastic has a density of about 160 lb per square inch when dried 146 lb per square inch and when fired 142 lb per square inch.

The First Iron Steamer

By H. PHILIP SPRATT

IRON hull construction was no novelty in 1821, when the flat bottom for the first iron steamer came to be laid down. As early as 1777 a small pleasure boat was made of sheet iron[1] on the banks of the River Foss in Yorkshire ; it was 12ft long and 6ft wide. Ten years later, in 1787, an iron canal boat named the " Trial," of about 40 tons loaded displacement, was built by one John Wilkinson at Willey, in Shropshire ; it was 70ft long and 6·7ft wide.[2] The hull plates were 0·312in thick and were secured with rivets, but the stem and stern posts were made of wood, the gunwales were lined with wood, and the beams were made of elm planks.

The first commercial vessel to be constructed entirely of iron was the " Vulcan," built in 1818 by Thomas Wilson at Faskine, Scotland, to the plans of Sir John Robertson, for canal use. The hull was 63ft long, 13ft wide, 5ft deep, and 4ft draught laden,[3] built of iron plates on flat bar frames ; all the frames and stanchions were forged by hand.[4] About this time the timber suitable for ship construction had become scarce and expensive, and naval architects were forced to consider the use of iron. At first this innovation met with serious opposition ; many experienced shipbuilders declared that to build vessels of a heavy metal was " contrary to Nature."

However, the first iron steamer, the " Aaron Manby," was laid down in 1821. The pioneers of this enterprise were her namesake, Aaron Manby (master of the Horseley Ironworks, near Tipton, Staffordshire), and his eldest son, Charles Manby, in association with Captain (later Admiral Sir) Charles Napier, who had entered into a speculative attempt to promote the use of iron steamers on the River Seine.[5] The hull was constructed of iron plates, 0·25in thick, with a flat bottom[6] and square stern. The fore-and-aft seams were lapped and riveted ; the ribs consisted of angle iron. The keelson was of wood, and wooden bearers were provided under the engines. The one deck, and the beams which supported it, were also of wood. The vessel carried a bowsprit above her raked stem, as shown in the illustration, reproduced from an old print (dated 1823), which has been presented to the Science Museum by Mr. John E. Manby, a descendant of the builder.

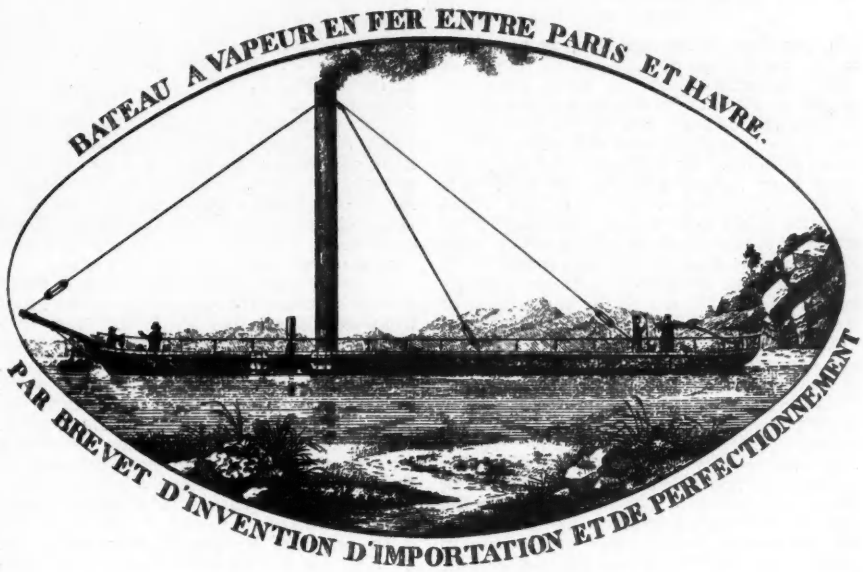
The " Aaron Manby " was decked in from end to end, so that all cargo was protected from the weather. It was also claimed to be protected from fire, since the vessel was constructed of iron. Two bulkheads were provided between the engine-room and the cargo, one of iron and the other of wood. All the interior of the boat was lined with wood, " to prevent heat being communicated to the cargo." The tall funnel, which rose about 47ft above the deck, was well stayed from the bowsprit, sides and stern, and appears to have served also as mast, in a similar manner to that of the P.S. " Comet " in 1812.[7]

For her propulsion, however, the vessel depended in the main upon her steam engines of 30 nominal h.p., constructed in accordance with the patent[8] taken out by Aaron Manby in 1821. These engines comprised two oscillating cylinders, about 27in diameter by 3ft stroke, which it is probable could have developed about 50 i.h.p. at full steam. Mr. Manby discovered later that his patent was invalid,[9] since oscillating cylinders had been tried by William Murdock as early as 1785. The idea was also adopted by Joseph Maudslay, whose oscillating marine engine of 1827 is still preserved at the Science Museum in London.[9]

Steam at low pressure (perhaps not more than about 2 lb per square inch above atmospheric) was supplied from two flat-sided iron boilers, 5ft wide, 12ft long and 6ft high, with rounded tops, placed athwartships. Each boiler contained two furnaces, 4·5ft long and 18in wide, with return flues. The total heating surface amounted to about 470 square feet and the grate area 27 square feet. The ashpits were open under the firebars, and the flues united into a common uptake to the funnel, which was about 3ft in diameter.

The intention at first was to use two pairs of paddle wheels ; but the plans were modified later, doubtless from considerations similar to those which affected the P.S. " Comet " of 1812, where the wash from the first pair of paddles had been found to interfere with the efficient action of the second. Therefore, in the end, the " Aaron Manby " was fitted with but one pair of paddle wheels. These were 12ft diameter ; and as the overall width of the vessel, for service on the Seine, could not exceed 23ft, the width of the paddle floats was restricted to 30in. These floats or oars were " feathered " by the bevel wheel mechanism of John Oldham, patented[10] in 1820. The paddle wheels would have made about 25 r.p.m. for a speed of 7 knots.

The hull was finished at the Horseley Ironworks about the end of 1821, transported in sections to London, and assembled at the Surrey Docks, Rotherhithe, under the supervision of Mr. Charles Manby.[11] The work was completed on April 30, 1822. Trials were run on the Thames,[12] between Battersea and Blackfriars, on Thursday, May 9, 1822, and it was stated[13] that the vessel " is the most complete specimen of workmanship in the iron way that has ever been witnessed, and draws one foot less water than any steamboat that has ever been built."



P.S. " Aron Manby," 1822

Under the command of Captain Charles Napier, and with Charles Manby as engineer, the " Aaron Manby " left the Thames with a cargo of linseed and iron. She crossed the Channel to Havre and proceeded up the River Seine to Paris, where she arrived on Tuesday, June 11, 1822,[14] much to the surprise of the inhabitants. One local newspaper[15] records that " Le bateau à vapeur en fer ' Aaron Manby,' Capitaine Napier, est arrivé avant-hier à huit heures du soir au port Saint-Nicolas." She is said to have been at first considered as an imposture,[16] because iron could never float. However, she was the first iron-built vessel that ever put to sea,[17] and the first vessel to proceed from London direct to Paris.[18]

Another similar iron steamer, the " Commerce de Paris," of 130-tons burden, was built in 1823 at the Horseley Ironworks and assembled in the Surrey Docks, London. She could not be admitted into France, however, because of new import restrictions. She had therefore to be shipped in sections and reassembled at Charenton, near Paris, where in 1819 Aaron Manby, in partnership with Daniel Wilson, a chemist from Dublin, had

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[1] *Gentleman's Magazine*, London, May, 1777, page 244.
[2] Grantham, John, *Iron Shipbuilding : with Practical Illustrations*, London, 1868, page 6.
[3] *Annual Register of the Year* 1820, London, 1822, Part II, page 1371.
[4] THE ENGINEER, London, January 21, 1898, page 50.
[5] Napier, E. H. D. E., *The Life and Correspondence of Admiral Sir Charles Napier*, London, 1862, Vol. I, page 120.
[6] Field, Joshua, *Diary of a Tour in the Midlands*, 1821. Manuscript in Science Museum Library, London. Printed, with introduction and notes by John W. Hall, in *Trans. Newcomen Society*, London, Vol. VI, 1925–26, page 23.
[7] Spratt, H. P., *Merchant Steamers and Motorships*, Science Museum, London, 1949, Part II, page 92.
[8] Manby, Aaron, *Oscillating Steam Engines*, Specification No. 4558, Great Seal Patent Office, London, July 9, 1821.
[9] Spratt, H. P., *Marine Engineering*, Science Museum, London, 1953, Part II, pages 25–26.
[10] Specification No. 4429, Great Seal Patent Office, London, June 9, 1820.
[11] Manby, John E., " An Early Iron Ship," *Country Life*, London, November 23, 1951, page 1721.
[12] *Morning Chronicle*, London, May 14, 1822.
[13] *The Courier*, London, May 15, 1822.
[14] *Journal des Débats*, Paris, Juin 11, 1822, page 3.
[15] *Le Constitutionnel*, Paris, Juin 13, 1822, page 4.
[16] Napier, E. H. D. E., *op. cit.*, Vol. I, page 121.
[17] *Journal des Débats*, Paris, Juin 16, 1822, page 2.
[18] Pâris, Vice-Amiral Edmond, et Bonnefoux, Bon Pierre M. J./de, *Dictionnaire de la Marine à Voile et à Vapeur :* Tome II, *Marine à Vapeur*, Paris, 1849, page 503.
[19] Molard, M., " Rapport sur les Fonderies et Etablissements d'Industrie de Messrs. Manby et Wilson à Charenton, près Paris," *Bulletin de la Société d'Encouragement pour l'Industrie Nationale*, Paris, Tome XXIV, 1825, page 125.
[20] Tourasse, M., et Mellet, F. N., *Essai sur les Bateaux à Vapeur*, Paris, 1828–29, page 107.
[21] Spratt, H. Philip, *Transatlantic Paddle Steamers*, Glasgow, 1951, page 22. See also " Le Premier Vapeur Transatlantique de la France," *Revue Trimestrielle Canadienne*, Montreal, Hiver, 1950–51, page 409.
[22] Grantham, John, *Iron as a Material for Shipbuilding*, London, 1842, page 7.
[23] *The Artizan*, London, November, 1849, page 259.
[24] Preble, Geo. H., *Chronological History of the Origin and Development of Steam Navigation*, Philadelphia, 1883, page 122.
[25] Information from Mr. C. E. C. Townsend, Port of London Authority.

founded the important ironworks of Messrs. Manby, Wilson, Henry et Cie. Two further iron steamers were later constructed at Charenton,[19] which realised a mean speed of 7 knots[20] in service on the River Seine ; and here in 1824, under the superintendence of Charles Manby, was constructed the machinery for the wooden P.S. " Caroline," the first steam auxiliary vessel in the French Navy and the first French steamer to cross the Atlantic.[21]

The " Aaron Manby " is said to have run aground several times in the Seine, with cargo aboard, but never to have required repairs to her iron hull.[22] In 1830 she was sold, and in 1836 she was at Nantes, in service on the River Loire. The vessel is stated to have been still at work in 1842, still in good condition in 1849,[23] and to have been broken up in France in 1855.[24] Principal dimensions[25] of the P.S. " Aaron Manby " were as follows : Burden, 116 tons ; length overall, 120ft; length between perpendiculars, 106·8ft ; breadth of hull, 17·2ft ; breadth over paddle wheels, 23ft ; depth in hold, 7·2ft ; draught, 3·5ft.

Some Foreign Civil Engineering Schemes of 1952

No. I

IN our issue of January 16th, we completed the publication of our annual review of civil engineering works, in which some examples were given of works in progress during 1952 in this country, and of works in various overseas countries with which British firms were concerned. By contrast, this article reviews some foreign works of the year. It is possible to mention only one or two representative works from several countries, but an attempt has been made to concentrate on some of the major works of the year, and on some others which made use of methods which are relatively unfamiliar here. It will be found that most of the examples given are of hydro-electric schemes. This fact may be accounted for by the preponderance of these schemes in the development of many countries at the present time, and partly from the fact that a large hydro-electric scheme often seems the best representative choice of a country's civil engineering generally. Several large-scale projects started in the years just after the war have now been completed, and 1952 saw the commissioning of two of the three largest hydro-electric power stations in Europe—at Harspranget in Sweden, and at Donzere in France, both of which compare in size with the power station at Genissiat, which has now been in operation for several years. The opening of the Amsterdam-Rhine canal also took place during 1952. These important civil engineering events in Europe will, however, be referred to later on in this article ; to start with, some examples are given of works in North America.

Canadian Hydro-Electric Progress

Since the war a considerable expansion in the hydro-electric resources of Canada has been in progress, and in 1952 a number of important schemes were under construction. Just over a million horsepower (about 750MW) of new generating capacity was brought into operation during the year, and the total installed capacity of hydro-electric plant in Canada is now given as 14,304,230 h.p., which is estimated to be about 22 per cent of the known resources. A number of the more attractive sites within convenient distances of the centres of population have already been developed, but it is nevertheless considered that the basic power demands of Canada's expanding economy will be met in large measure from hydro-electric sources for some time.

The province of Quebec, which is rich in water power resources, brought into operation just over half of the total figure for new plant given above. Four large units, totalling 164MW, were installed in the Beauharnois No. 2 power station on the St. Lawrence River as part of a development which will have an ultimate installed capacity of 1050MW. The Chute-du-Diable scheme of the Aluminium Company of Canada, on the Peribonka River, was also substantially completed in 1952, with a total installed capacity of 205MW in five units.

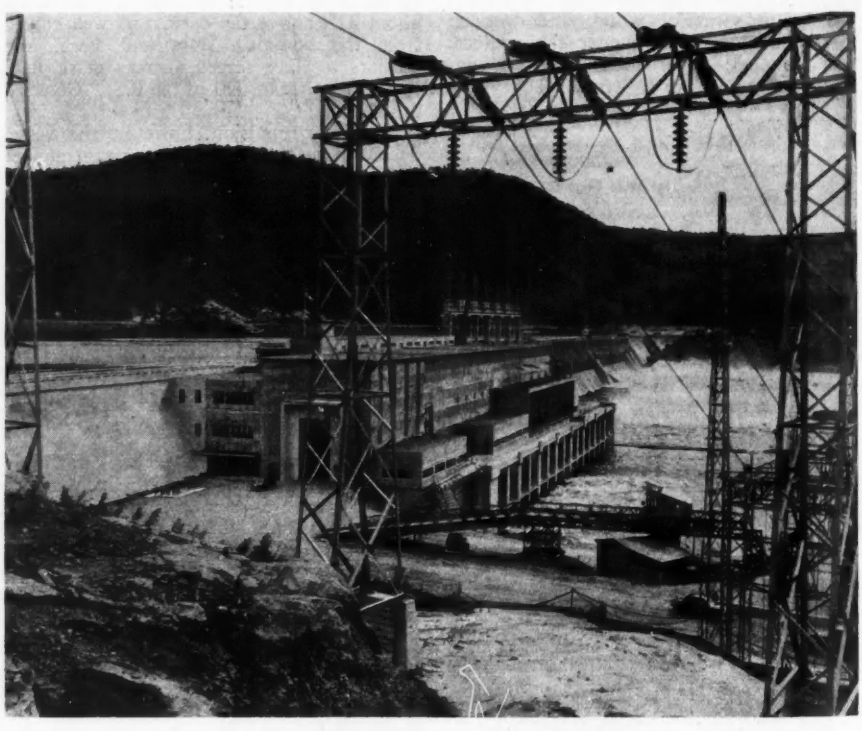
The same company made good progress during the year on the Nechako-Kitimat development in British Columbia. No definite plans have yet been made for expansion beyond the present programme for this scheme, which envisages an installation of 314MW in three units, to be completed in 1954, although the ultimate capacity of the scheme is estimated at more than 1500MW. The Kenney dam on the Nechako River was practically completed by the end of the year and storage of water was started in October. Four miles of tunnel, 25ft in diameter (the length of the completed tunnel will be 10 miles), was completed in 1952, and excavation for the underground power station was well advanced.

In Ontario, the Hydro-Electric Power Commission continued the construction of two major hydro-electric schemes in 1952. The Otto Holden generating station, on the Ottawa River above Mattawa, was officially opened last June, and the last of the eight sets, totalling about 200MW, is expected to be in service early this year. The dam and power station are shown in the illustration below ; the station was named after the engineering assistant general manager of the Commission, and forms the interconnection between the North-Eastern and Southern Ontario power systems.

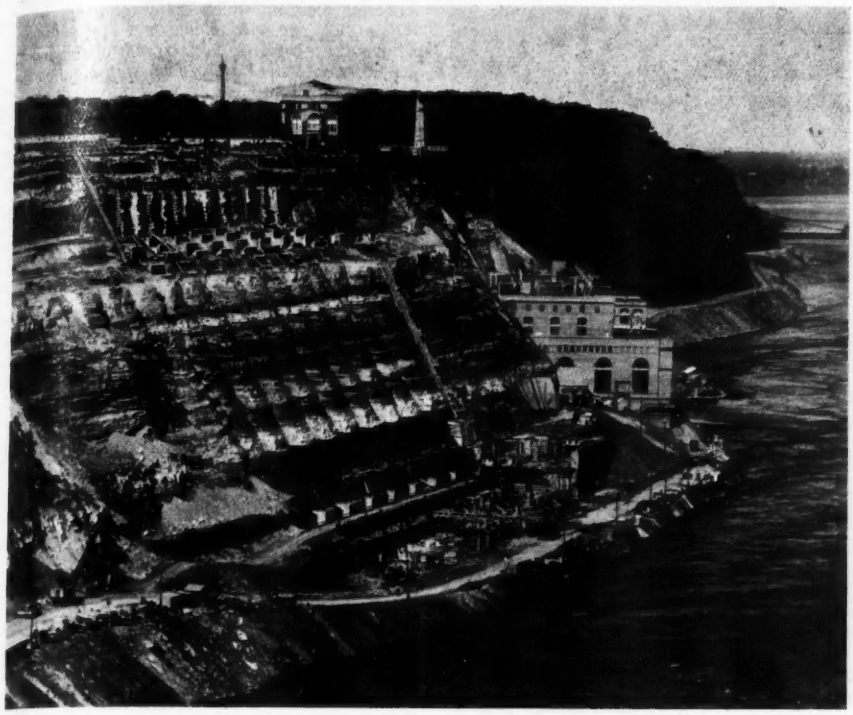
The second of the schemes under construction in 1952 for the Hydro-Electric Power Commission of Ontario involved a power station close to Niagara Falls—the Sir Adam Beck-Niagara generating station No. 2, as it is called—which is of more than usual interest on account of both its size and position. The scheme consists of twin intake structures and diversion tunnels, leading to a single open channel aqueduct, and thence to the penstocks and the power station. The two intakes will each consist of a 500ft long gathering tube, placed along the shore line of the Niagara River in such a manner as to take advantage of the main current (the intakes were designed from model tests) and situated about 2 miles above the falls. Each intake is to lead to a tunnel, 5½ miles long, with a finished diameter of 45ft and a 3ft thick concrete lining. The capacity of each of these intakes and tunnels will be 20,000 cusecs, and they will pass under the city of Niagara Falls. The two tunnels will emerge into a canal 2¼ miles in length, which will run mainly unlined through rock, its depth of 70ft and width of 200ft giving a capacity of 40,000 cusecs. Near the forebay of the new power station the canal is to intersect the diversion canal of the existing No. 1 station, and the flow of the two canals will be redistributed at this intersection ; further redistribution will again occur at the two power station forebays, which are also to be connected together.

The new generating station will have an installed capacity of 900MW in twelve units. It will be 931ft long, 63ft wide and 50ft high, and will be built beside the existing station. The gross head will be 295ft. Both stations are named after the first chairman of the Ontario Hydro-Electric Power Commission ; the first was completed in 1921, and was for many years the largest hydro-electric power station in existence, with its installed capacity of nearly 400MW. The size of the new station may be compared with the Grand Coulee installation in the U.S.A., where the installed capacity is about 2000MW.

Work on the new scheme was started in 1951, and it is expected that the first four turbo-alternator sets will be in service in 1954, three in 1955, and the last five in 1956–57. The estimated cost of the scheme is 300 million dollars. The very considerable volume of spoil from the various excavation works is to be tipped in disposal areas on the outskirts of the town, which will be graded and soiled on completion of the work. Our illustration shows the progress of the work at the power station site, the position of the various penstocks down the 300ft Niagara cliff, and the power station substructure being



Otto Holden Generating Station, Ontario



Construction of Sir Adam Beck-Niagara No. 2 Generating Station

clearly indicated. The No. 1 power station and headworks are shown in the background.

Water Power in the United States

The most important American civil engineering scheme to be completed in the past year was the Hungry Horse dam of the U.S. Bureau of Reclamation in North-Western Montana, which was dedicated by President Truman on October 1, 1952. As part of the ceremony at the dam, President Truman put into operation the first 71·25MW generator of the Hungry Horse power station, thus starting the delivery of the first electric power in the Pacific North-West from a post-war Federal hydro-electric scheme. Almost all the concreting, which involved 3,100,000 cubic yards, was completed at the time of the dedication.

The Hungry Horse dam, which is shown approaching completion in the accompanying illustration, is situated on the south fork of the Flathead River, near the town of Kalispell, Montana, and it is one of the major schemes of the U.S. Bureau of Reclamation in the multi-purpose development of the water resources of the Columbia River drainage basin. The dam is a concrete arch gravity structure, 2115ft long at the crest and 564ft high. It has a maximum base width of 330ft and is surmounted by a 30ft wide road. The elevation of the crest of the dam is 3565ft above sea level.

The structure is not "the fourth largest and the third highest concrete dam in the world," as stated in our issue of October 31st last. It is exceeded in height by Hoover dam (726ft) and Shasta dam (602ft), as noted then, but it is also not as tall as Tignes dam in France. The Tignes dam is mentioned later in this review ; its height is 590ft and it is a true arch dam with a base width of 143 ft. For those interested in such comparative figures it may be recalled that the Grand Dixence gravity dam under construction in Switzerland will have a height of 922ft, and the arch dam of Mauvoisin, in the same country, will be 775ft high. Two designs are under consideration for an arch dam at Vajont, in Italy, with heights of 837ft and 670ft respectively. In India, the Bhakra dam under construction in the Punjab (THE ENGINEER, August 10, 1951) will be a gravity structure, 680ft in height.

Hungry Horse dam has created a reservoir with a useful storage capacity of almost 3,000,000 acre-feet. The power station has been built across the river at the downstream toe of the dam and will have an installed capacity of 285MW in four sets, the last of which is scheduled for operation at the end of this year.

Another important flood control structure of the Bureau of Reclamation under construction in Montana in 1952 was the Canyon Ferry dam on the Missouri River. About 400,000 cubic yards of concrete will be required for this gravity structure, which will be 225ft high with a crest length of 1000ft. The reservoir will have a capacity of 2,051,000 acre-feet. Flood waters from a catchment area of 15,860 square miles will be stored in the reservoir and will make possible the irrigation of about 310,000 acres of new land and the provision of supplemental irrigation supplies for 196,000 acres now inadequately served. The power station will have an installed capacity of 50MW and it will generate 285 million kWh annually after full development of upstream irrigation.

Work also proceeded during the past year on the Boulder Canyon project of the Bureau of Reclamation to complete the power station of the Hoover dam on the Colorado River. The remaining two 82·5MW and one 50MW turbo-generator units were being installed, and the station will thus reach its ultimate rated generating capacity of 1317·5MW in due course. While no major new dam structures were being built by the Tennessee Valley Authority, additional generating units were being installed at several power stations. In accordance with the Pick-Sloan plan for the development of the Missouri River basin, considerable work proceeded during 1952 in this area, both with dam construction and local flood protection. The major schemes of the U.S. Army Corps of Engineers in the basin were the Fort Randall, Gavins Point and Oahe dams in South Dakota, the Garrison dam in North Dakota, the Fort Peck dam in Montana, and the Harlan County dam in Nebraska.

Highway Engineering Works in the U.S.

For many civil engineers in this country, probably the most enviable aspect of the American civil engineering scene is the amount of capital available for new motorways, and the works such as bridges and tunnels which they involve. The New Jersey Turnpike has already been described in these columns (THE ENGINEER, August 8, 15 and 22, 1952), but it is not inappropriate to mention it again here, as all but 9 miles of its total length of 118 miles were put into service on January 15, 1952. Although several serious accidents occurred during severe fog on the northern part of the road recently, the scheme is nevertheless considered the most successful American highway development of recent years. The Turnpike Authority has now announced the issue of a new revenue bond, of which some 20,000,000 dollars will be employed to finance improvements for the toll highway which have become necessary already because of a traffic density far beyond that expected originally. The improvements include two additional traffic lanes between Camden and Woodbridge, New Jersey, and between the Lincoln tunnel and the George Washington bridge. Plans are now being made for the construction of three extensions to the Turnpike : a Jersey City expressway as a link

Hungry Horse Dam

Chesapeake Bay Bridge

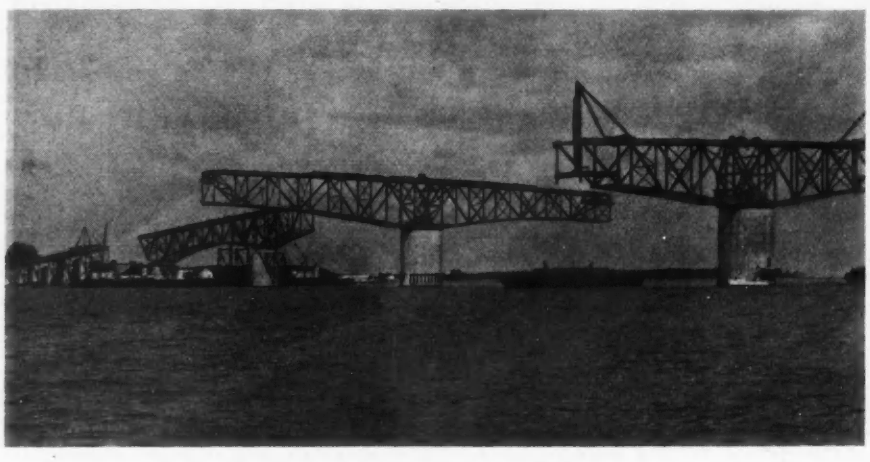
to the Holland tunnel connecting with New York City ; an expressway crossing Newark Bay ; and a connection to the Pennsylvania Turnpike near Florence, New Jersey, across the Delaware River.

An important bridge opened to traffic during 1952 is the Chesapeake Bay bridge, which is illustrated herewith. In the same manner as the recently completed New Jersey Turnpike and the Delaware Memorial Bridge enable traffic along the Atlantic Coast to bypass the cities of Trenton, New Jersey, Philadelphia, Pennsylvania, and Wilmington, Delaware, this new bridge and causeway bypasses the city of Baltimore, Maryland, so that it is now possible to motor from New York City to Washington, D.C., along first-class highways without having to pass through any of the larger eastern cities. The overall length of the bridge is 7·73 miles, and it crosses the Chesapeake Bay from Sandy Point, on the western shore near Annapolis, to Stevenville, where Kent Island, stepping out from the eastern shoreline, narrows the bay to about 5 miles. The bridge joins the eastern and western sections of U.S. Highway 50, replacing a ferry. The central suspension bridge has a main span of 1600ft with side anchor spans of 661ft each. The bridge provides a 28ft roadway with emergency footways 18in wide, collision kerbs and handrails. Work on the scheme commenced in January, 1949, and the bridge was opened to traffic on July 30, 1952.

Another interesting highway bridge completed in 1952 is the George P. Coleman Memorial Bridge over the York River between Yorktown and Gloucester Point, Virginia, on the east coast of the United States. The bridge is shown approaching completion in the accompanying illustration. It has an overall length of 3750ft and each of the swing spans is 500ft long and weighs 1200 tons. The bridge replaces a ferry, which used to carry the heavy north-south traffic on U.S. Route 17, known as the American Coastal Highway. A double-leaf swing-span design was chosen for the bridge because of objections to a high-level suspension span or a double-leaf bascule whose high framework, it was maintained, would have clashed æsthetically with the " colonial atmosphere " of Yorktown. The two 500ft swing spans provide, when open, a clear 450ft channel with a water depth of 80ft. When the moving spans are closed the vertical clearance is 60ft. Over the river itself there is 2540ft of deck truss construction laid out symmetrically about the central 500ft channel span. The flanking spans back from the channel are 390ft, 350ft and 280ft respectively. Beyond the deck trusses on the north side are eight 90ft approach girder spans. On the south side six approach girder spans comprise four at 90ft and two at 65ft. The bases for the six river piers are caissons with heights varying up to 110ft. The two central caissons are topped by cylindrical concrete piers on which the swing spans pivot. These piers are 44ft in diameter and 99ft high above the top of the caisson, 40ft of this height being under water. Machinery for operating the swing spans is situated on the bottom chords of the swing spans, directly over the piers, and the electrical equipment is housed within the piers. The other four river piers, which are rectangular in shape, are from 32ft to 44ft in height above the water. All the river pier bases were constructed by the open-dredge caisson method. The caisson shells were fabricated in a shipyard and subsequently towed to the bridge site. The caissons had to be sunk to a depth of up to 150ft below water level, involving one of the most difficult of recent bridge pier foundation operations in America. Construction of the scheme was started in December, 1949, and the bridge was opened on May 7, 1952.

Turning now to highway tunnels, the Elizabeth River tunnel between the cities of Norfolk and Portsmouth, Virginia, was opened to traffic on May 23, 1952. It is described in some detail on page 178. Construction commenced on September 25, 1952, of another important American tunnelling scheme, a third " tube " for the Lincoln tunnel, which crosses the Hudson River, connecting the west side of Manhattan with Weehawken, New Jersey. The " tube " will have a portal-to-portal length of 7944ft, an external diameter of 31ft and a 21ft 6in wide roadway.

(To be continued)



George P. Coleman Memorial Bridge

Lloyd's Shipbuilding Returns

THE shipbuilding returns for the quarter ended December 31, 1952, have been issued by Lloyd's Register of Shipping. In Great Britain and Northern Ireland the work in hand consists of 336 steamships and motorships of 2,146,402 tons gross, representing an increase of 83,920 tons over the previous quarter ; of the total, 102 ships of 586,287 tons were fitting out and the remainder were still to be launched. During the quarter sixty-three ships of 389,800 tons were commenced, sixty-six ships of 373,177 tons were launched and the ships completed numbered sixty-six of 324,438 tons, while work was suspended on four ships. A total of ninety-six ships of 671,843 tons was under construction for registration abroad, 26,826 tons more than at the end of September last and representing 31·3 per cent of the tonnage being built. Oil tankers of 1000 tons and upwards under construction totalled 103 ships of 1,214,864 tons, 65,388 tons more than the last quarter and 56·6 per cent of the tonnage building. By the end of the quarter plans had been approved for ships totalling 2,606,478 tons, a decrease of 77,785 tons since the last quarter, of which 61·5 per cent represented oil tankers. Abroad 843 steamships and motorships of 3,972,183 tons gross were under construction ; this is an increase of 169,792 tons over the previous quarter and does not include returns for China, Poland and Russia. During the last three months 225 ships of 1,059,716 tons were commenced and 239 ships of 1,016,002 tons were launched, while 237 ships of 839,456 tons were completed and work was suspended on thirty-nine ships of 61,111 tons. The number of oil tankers totalled 171 ships of 2,062,251 tons, representing 284,753 tons more than in September last and 51·9 per cent of the tonnage building abroad. A summary of world shipbuilding shows that 1179 ships of 6,118,585 tons gross were under construction, of which 35·1 per cent was being built in Great Britain and Northern Ireland. The total includes 187 ships of between 10,000 tons and 15,000 tons, fifty ships of between 15,000 tons and 20,000 tons and twenty-five ships of between 20,000 tons and 30,000 tons. Oil tankers under construction amounted to 274 ships, representing 3,277,115 tons, and 53·6 per cent of world construction. Of the steam and motorships building throughout the world, 3,846,907 tons or 62·9 per cent are under the inspection of Lloyd's Register and of this total 2,048,994 tons are under construction in Great Britain and Northern Ireland.

Bankside Power Station

No. II—(*Concluded from page 144, January 23rd*)

The decision to rebuild the old power station at Bankside was taken originally in 1939, but the work was deferred for the duration of the war. When the matter was reopened at the end of the war there was strong public opposition to the building of a new power station on a site reserved for development with offices, light industries and buildings for cultural uses. A public inquiry was held and the outcome was that, because of the difficulty of finding a suitable alternative, the Government authorised the new construction. To safeguard the amenities it was stipulated that the boilers should be fired with oil instead of coal, that gas washing plant should be installed, and that the station building should be in harmony with its surroundings on the site, when fully developed.

STEAM for the two turbo-alternators in the first half of the steam is to be generated by four Foster-Wheeler oil-fired boilers, two of which are now installed, together with the first generating set. It is intended that three of the boilers, operating at about 90 per cent of their maximum output, should be capable of supplying the steam needs of two generating sets at full output, leaving the fourth boiler as standby.

The main boiler particulars are given in the Table and the general arrangement is given in the accompanying line drawing. It will be seen that each unit is a single-drum, natural-circulation, water-tube boiler with water-cooled combustion chamber, primary and secondary horizontal drainable convection type superheaters, plain steel tube economiser and primary and secondary air heaters. The secondary air heater is of plain steel tubular construction, and the primary air heater, which handles the cooler gases, is of gilled cast iron to resist corrosion. To allow thermally correct balance of work to be maintained between the boiler, economiser and air heater there is a small bank of tubes for convection heating between the primary superheater and the economiser.

The superheater and convection heating tubes are widely pitched so that slag accumulations will fall clear when removed from the tubes.

Provision is made for water washing the primary and secondary superheaters, boiler convection surface, economiser, and primary air heater, which are arranged in separate compartments with a number of hoppers for the collection and removal of the effluent. A small-capacity extracting plant has been provided to deal with accumulations of dust.

TABLE—*Main Particulars of Boilers*

	Normal economic rating	Maximum continuous rating
Evaporation, lb/hr	300,000	375,000
Final steam pressure, lb/sq in	950	950
Final steam temperature, deg. Fah.	925	925
Feed temperature at economiser inlet, deg. Fah.	370	370
Feed temperature at economiser outlet, deg. Fah.	475	500
Air temperature at air heater inlet, deg. Fah.	100	100
Air temperature at air heater outlet, deg. Fah.	520	540
Final gas temperature, deg. Fah.	331	350
CO_2 at furnace exist, per cent	13·7	13·7
CO_2 at induced draught fan, per cent	12·02	12·0
Total draught loss, inches W.G.	5·7	8·89
Furnace liberation, B.Th.U./cu ft.	17,900	22,500
Gross thermal efficiency, per cent	86·5	85·9
Oil consumption, lb/hr (calorific value, 18,250 B.Th.U./lb)	21,300	26,800
Furnace volume, cu ft	21,750	
Furnace dimensions (between centres of tubes) :		
Wide	22ft 4in	
Deep	18ft 0in	
High	36ft 0in	
Heating surface :		
Water walls, sq ft	13,025	
Convection bank, sq ft	4,230	
Risers from convection bank, sq ft	2,460	
Primary superheater, sq ft	7,543	
Superheater connecting tubes, sq ft	1,625	
Secondary superheater, sq ft	6,260	
Economiser, sq ft	11,540	
Primary air heater (cast iron), sq ft	22,048	
Secondary air heater (steel), sq ft	50,000	

Control of the final steam temperature at 925 deg. Fah. from 280,000 lb of steam per hour up to full load is achieved by Foster-Wheeler condenser control in which a portion of the feed water by-passes the economiser and traverses two banks of tubes in the primary superheater inlet header. Some of the steam entering the superheater is therefore condensed and must be re-evaporated before superheating can take place. By varying the quantity of by-passed boiler feed water and, therefore, the amount of condensate needing re-evaporation the final steam temperature is under control.

There are twelve Todd oil burners per boiler and, as shown by one of our illustrations, they are grouped in two rows in the front wall of the combustion chamber. Each burner is provided with a gas pilot light and is fed with oil by pumping and heating units as described in last week's issue. The fuel oil supply is controlled by varying the speed of the pump and by shutting off burners between full and half-load. Below half-load, control is effected by varying the number of burners in use, with maximum pressure in the line. To provide automatic safeguard in the event of fan failure or low water level, fuel oil shut-off valves are provided in the supply manifold to each row of burners, and are interlocked with fan starters and the water level gauge.

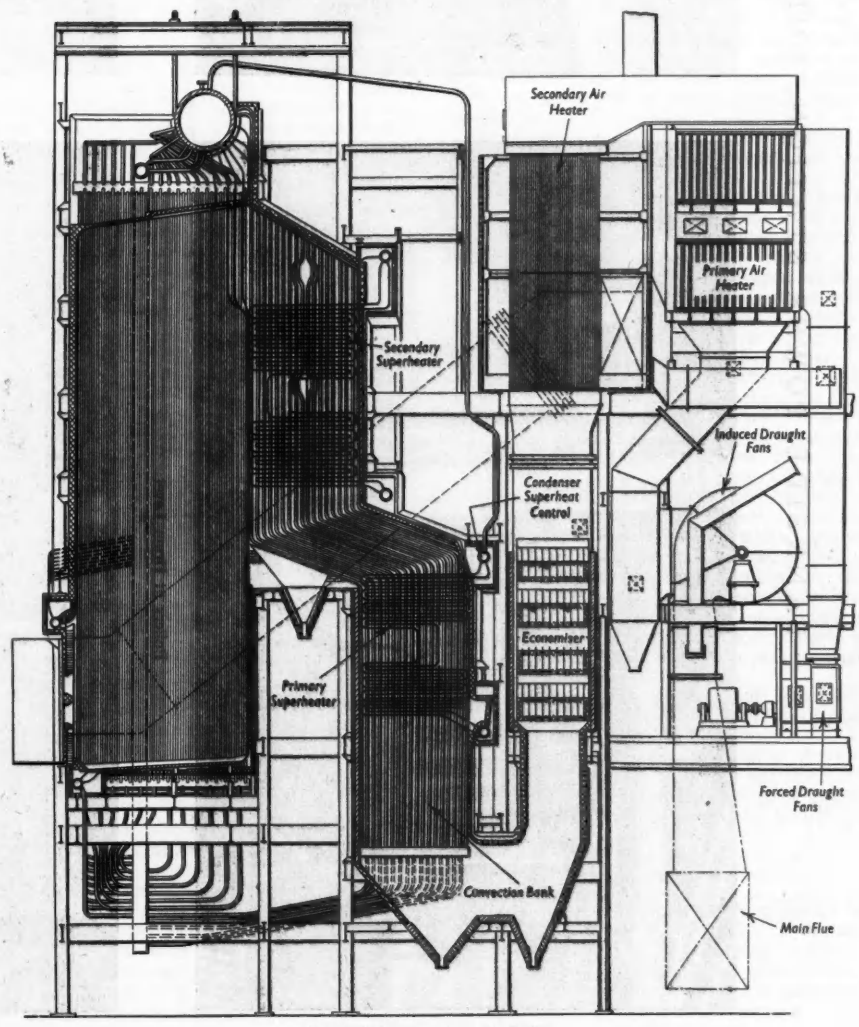
Combustion air is supplied by dual forced draught fans, each driven by a two-speed electric motor. Volume regulation is obtained by movable inlet vanes controlled by electrically operated torque units which are equipped with standby manual controls. Air is discharged from the forced draught fans to the primary and secondary air heaters and thence through ducts on either side of the boiler to the burner fronts.

On leaving at the top of the combustion chamber the products of combustion pass in turn over the secondary and primary superheaters, the boiler convection section, the economiser, the secondary and primary air heaters, and are removed by dual induced draught fans, which are similar to the forced draught fans and are controlled similarly. The gases are discharged by the fans into the main flue which serves the four boilers.

Dampers for controlling the flow of air and flue gases are installed in the induced draught and forced draught fan discharges, in the air heater by-pass duct and in the boiler ventilating duct.

The air heater by-pass duct enables up to 50 per cent of the air, at normal economical rating, to by-pass the primary air heater and the first pass of the secondary air heater when lighting up the boiler and during periods of low load. Proper ventilation of the boiler when completely shut down is ensured by means of a small ventilating duct leading from the gas duct between the primary and secondary air heaters up to and through the boiler-house roof. Any noxious gases are removed by an exhauster fan fitted in the cowl. Further protection is provided by a duct to the atmosphere from a point between the two sets of dampers in the induced draught fan discharge duct. Any gases that may leak up from the main flue while the other boilers are working are thereby carried off.

Each boiler has nineteen electrically operated



Vertical Section through Boiler

BANKSIDE POWER STATION, LONDON DIVISION, B.E.A.

Boiler Control Aisle

Power Station Control Room

Boilers at Drum Level

No. 1 Turbo-Alternator and Control Panel

steam soot blowers, which are automatically operated in sequence from a control cubicle on the firing floor. Soot hoppers are provided below the secondary superheater, the boiler convection bank, the economiser and the primary air heater. These hoppers are connected to a dry dust extraction plant and are also suitably lined and positioned to meet the requirements of water washing.

Feed water supply to the boiler is controlled by a "Flowmatic" feed-water regulator which can be fed from the main or auxiliary feed lines.

On the firing floor there is a control and instrument panel on which pressures, temperatures, draughts, flows, &c., at different parts of the boilers are indicated. The fan motors, fan vanes, dampers, main steam stop valves, feed valves and oil pressure valves are remotely operated from the panel. A separate panel carries the soot blower controls.

For boiler test purposes there is a fuel oil weight tank whereby oil quantities can be measured accurately.

Turbo-Alternators

The two generating sets for the first half of the station are B.T.H. equipments consisting of two cylinder turbines with double-flow, low-pressure turbines coupled to air-cooled alternators having external separately-driven fans. One of our illustrations shows the first set. The turbines are designed for a continuous maximum economic rating (c.m.e.r.) of 60MW with stop valve steam conditions of 900 lb per square inch and 900 deg. Fah., the vacuum at exhaust being 29in Hg. There are five stages of feed heating, the final feed temperature at c.m.e.r. being 380 deg. Fah. and the steam consumption 8·503 lb per kilowatt-hour. The alternators have a maximum continuous rating of 60MW at 0·875 p.f., and a terminal voltage of 15kV when driven at 3000 r.p.m.

The chimney tower, which is centrally situated on the north side of the building, consists of a single tower, 40ft square, rising some 300ft from street level. It is steel framed, having at each corner a cruciform stanchion tapering from 5ft 8in by 5ft 8in at the bottom to 3ft 4in by 3ft 4in at the top. External brickwork embodying vertical ornament and tapering at 1 in 120 is supported by steel joists built in and carried on the corner stanchions. The tower houses four octagonal cast iron flues, 11ft diameter, which rise from a plenum chamber at level 130 N.D. The cast iron flues are supported on steel flooring every 23ft and are provided with expansion joints to accommodate temperature movements.

Condensing and Feed Heating Plant

Each turbo-alternator has a Richardsons-Westgarth twin condensing plant with a total cooling surface of 50,000 square feet built up of 1in o.d. (18 s.w.g.) tubes, 22ft long, and taking 40,000 gallons of water per minute in two passes. For each condensing plant there are two 100 per cent, three-stage, steam-operated air ejectors.

The condensing and feed-heating plant operates on a closed-feed system in which the necessary flexibility between condensate quantity from the set and feed demand of the boilers is provided by a control valve actuated by the water level in the condensate receiver below the main condensers. Motor-driven extraction pumps discharge the condensate from the receiver through the air ejector, drain cooler, gland heater and low-pressure feed heaters in turn, and thence to a spray type deaerator situated in the basement. Pumps extract the water from the deaerator, discharging it into the boiler feed pump suction. The boiler feed pumps discharge the feed through three high-pressure heaters in series into the boiler feed mains. Arrangements are made to enable fully deaerated water to be used for topping up banked boilers even when the main sets and feed heating plants are shut down. Heating coils are arranged in the deaerator tank and small pumps are provided for recirculation and discharging feed to the boilers.

For turbine steam consumption test purposes a permanent test station with a calibrated test venturi and indicating, recording and integrating instruments has been provided.

When required the total feed flow from either machine can be diverted through the test station and double-valve shut-off is provided on all common mains and services between the two machines, so that one set may be quickly and easily isolated when accurate test data are required.

There is a common feed pump suction and delivery main and three 100 per cent motor-driven and one 100 per cent steam-driven feed pumps are provided for the two turbo-alternators. The pumps operate at 3000 r.p.m. and generate a pressure of 1250 lb per square inch when delivering 600,000 lb of water per hour at a temperature of 246 deg. Fah. Automatic thermally-operated leak-off valves are provided to safeguard the pumps at periods of low flow.

If the feed range pressure falls below a predetermined point, the turbine-driven pump cuts in automatically. The turbine exhausts to atmosphere only.

Circulating Water System

The intake shaft to the circulating water system is 18ft in diameter, is situated at the west end of the jetty and leads down to a 10ft diameter cast iron tunnel, concrete lined, which has been driven in clay. The water flows to the penstock chamber, which is incorporated in the chimney foundation and thence to the reinforced concrete suction chamber in the basement.

From this chamber water is drawn by the circulating water pumps. Four vertical-spindle, motor-driven centrifugal pumps, each capable of handling 1,640,000 gallons per hour have been provided for the first two machines. Each pump discharges through a rotary water strainer to 42in and 60in diameter cast iron pipes to the condensers. From the condensers the water flows to the discharge culvert constructed beneath the basement floor in reinforced concrete, asphalt lined. This culvert runs westwards through the retaining wall to the 18ft diameter discharge shaft, where the discharge penstock is fixed.

A 10ft diameter concrete-lined, cast iron discharge tunnel carries the water to the north side of the river close to Blackfriars Bridge, where a cast iron shaft 18ft diameter leads up to river bed level. This tunnel was driven in clay and is approximately 60ft below ground level.

Transformers

Each generator is connected to a 66kVA, three-phase, delta-star transformer, stepping up from 15kV to 66kV. Each generator transformer contains in the same tank a 5000kVA, three-phase, delta-interstar unit transformer, stepping down from 15kV to 3kV. The unit transformers, together with two 7000kVA, three-phase, delta-star house service transformers, stepping down from 66kV to 3kV, supply the station auxiliaries.

Power is supplied to the London Electricity Board's distribution network through four 25,000kVA, three-phase, delta-star transformers, stepping down from 66kV to 22kV, and four 15,000kVA star-star transformers, stepping down from 66kV to 11kV.

The transformers are housed in open-fronted cubicles, facing south, on the ground floor of the switch house. There are also seven 500kVA, three-phase, delta-star transformers, stepping down from 3kV to 415V, to supply the smaller auxiliaries. One set of three single-phase, oil-immersed busbar sectionalising reactors is installed in a cell adjacent to the transformers.

Switchgear and Neutral Earthing

The main 66kV, 2,500,000MVA switchgear is an ironclad installation situated on three upper floors of the switch house, the circuit breakers being on the upper floor, the selector switches immediately below, and the busbars on the lower floor. The busbars and connections are of the condenser-bushing type with all joints and tee connections contained in oil-filled sealing chambers.

All circuit breakers are electrically operated from a control room on the same level. This room, illustrated here, contains the control panels for the 66kV, 22kV, 11kV and 3kV switchgear, the relay panels being situated directly behind. The generator control desk is in the centre of the room and commands a view of all control panels. A portable synchronising cubicle can be seen in use in our illustration.

The distribution network is controlled by a 22kV, 500MVA, duplicate busbar two-section switchboard, and an 11kV, 350MVA duplicate busbar two-section switchboard, both being situated on the ground floor of the switch house. The 3kV, 150MVA, single busbar house service switchgear comprises a main switchboard in the switch house and a unit board associated with each generator in the mechanical annexe.

The 415V main and sub-distribution boards are stiuated in various parts of the building close to the auxiliary transformers associated with them.

Generators neutral points are earthed through voltage transformers. The neutrals of the 66kV and 22kV systems are earthed through limiting resistors, whilst the 11kV, 3kV and 400V systems are connected directly to earth.

Two 66kV cables run to Battersea generating station and two to Deptford generating station. Ten 22kV cables and twelve 11kV cables distribute power to the various substations of the London Electricity Board.

Flue Gas Treatment

Gas treatment plant is being installed to handle the sulphur dioxide content of the flue gases leaving the boilers. Here the gases will be scrubbed counter-currently in two series towers using Thames water with finely divided chalk added to it. Subsequently, the effluent will be oxidised by aeration with ceramic diffusers, the process being assisted by the addition of suitable catalysts.

The complete plant, half of which is installed, is designed to remove 95 per cent of the sulphur oxides contained in the flue gases resulting from fuel oil having a maximum sulphur content of 4 per cent. Two gas washing chambers, one for each half station, will be situated in the centre of the station between each group of four boilers. These chambers are built of cast iron plate, each chamber being 106ft high, 53ft wide by 48ft deep. Each chamber is packed to a depth of 55ft with timber scrubbers of "egg-box" construction and contains two absorption passes through which the gases pass in series, together with a transfer pass.

Above each absorption pass there are tanks from which the wash water is sprayed over the scrubbers through ebonite nozzles.

Hot gases from the boilers are discharged to a common mild-steel flue at basement level, and thence to the bottom of the washing chamber. The treated gases leave at the top and are discharged to a cast iron plenum chamber, whence the four cast iron octagonal flues receive the gases for discharge to the atmosphere. Each flue is fitted with a damper and each has a nozzle at the top so that at any station load above 25 per cent the gases may be discharged at a velocity of between 60ft and 120ft per second.

The wash water is pumped to the tanks through a 30in bore pipe by eight pumps (five initially installed) connected to the condenser circulating water discharge culvert. Each pump is designed to handle 220,000 gallons per hour against a total head of 175ft. Chalk is injected into the wash water by pumps situated beneath the terrace. The chalk is delivered and stored in the form of a 50 per cent slurry. The effluent from the chambers is acidic and is passed through rubber-lined pipes to 45ft deep aeration chambers, where air from a battery of compressors is released from ceramic diffusers to pass through the effluent.

The effluent passes through oil separators before joining the circulating water discharge for return to the river.

Provision is also made to by-pass the gas washing chambers and divert the gas direct to the stacks in an emergency, and complete instrumentation will be provided for the control of the washing process.

Auxiliary Plant

The main steam, feed and drain pipework is butt-welded throughout and all valves are similarly welded in. A complete recovery system has been installed for all high-pressure and low-pressure clean drains, blow-down receivers discharging drains to conservator tanks for pumping back to the system.

All dirty drains are discharged from receivers to drain sumps where compressed air-operated ejectors discharge to sewer.

All cooling and sealing water requirements are met by three auxiliary river pumps which discharge to high-level tanks in the boiler-house.

Two 500 c.f.m. air compressors are provided for general station services.

Throughout the station a " Mulsifyre " automatic fire-protection equipment has been installed to cover all important electrical plant and apparatus as well as the fuel oil and turbine lubricating system. Carbon dioxide equipment is also installed together with hydrants and portable hand appliances.

Two travelling cranes are installed in the turbine house, the maximum lift being 150 tons. Auxiliary hoists are provided for feed pump, circulating water pump and strainer handling.

PRINCIPAL CONTRACTORS

Foundations and superstructure, jetty and tunnel works, Sir Robert McAlpine and Sons; structural steelwork, gas-washing structure, penstocks, and turbine house cranes, Sir William Arrol and Co., Ltd.; h.p. boilers, Foster Wheeler, Ltd.; oil burning equipment, Todd Oil Burners, Ltd.; boiler piping, C. and A. Parsons and Co., Ltd.; turbo-alternators, British Thomson-Houston Company, Ltd.; condensing and feed heating plant, Richardsons, Westgarth and Co., Ltd.; feed pumps, condensate and de-aerator extraction pumps, Mather and Platt, Ltd.; high-pressure steam and feed valves, Dewrance and Co., Ltd.; high-pressure steam and feed pipework and high-pressure and low-pressure drain pipework, C. and A. Parsons and Co., Ltd.; oil handling plant, Young, Austen and Young, Ltd.; oil pumps, Stothert and Pitt, Ltd.; fuel oil tanks, Whessoe, Ltd.; circulating water pipework, Aiton and Co., Ltd.; circulating water pumps, Drysdale and Co., Ltd.; 66kV switchgear, Metropolitan-Vickers Electrical Company, Ltd.; 22kV switchgear, auxiliary 3kV equipment, Ferguson Pailin, Ltd.; 11kV switchgear, Reyrolle and Co., Ltd.; 66kVA reactors and 415V switchgear, British Thomson-Houston Company, Ltd.; 11kV and 22kV cables, Siemens Bros. and Co., Ltd.; transformers, Ferranti, Ltd.

A Rotary Compressor with Inbuilt Compression

The development of a new design of a positive variable displacement compressor by the British Internal Combustion Engine Research Association (B.I.C.E.R.A.), a rotary machine with inbuilt compression, is described. Comparisons are made with the Roots pressure charging system, design considerations are reviewed and a specification of a prototype compressor is given together with test results.

THE Roots type compressor could not have withstood the test of time unless it had a number of good points, and it was considered to be most important that these should not be lost in the search for improvement of its other features. The main good points are its light weight and small bulk, due partly to its economical geometry and much more to its high speed of operation. Lubrication is not required in the working space, and reasonable reliability can be obtained, but only when production and fitting limits are carefully controlled. A detrimental feature is the absence of internal compression, which limits the useful maximum delivery pressure to about 8 lb per square inch gauge and causes the peak efficiency to occur somewhere within the range of 2 lb to 5 lb per square inch gauge. Another detrimental point is the considerable leakage of air past the rotors, which not only causes a loss of overall efficiency, but also a rapid drop in delivery pressure when the speed is reduced and the delivery volume per revolution is kept constant. The rotors are complicated in shape and the surface has to be accurate to within fine limits ; also, if the rotors should touch a bad seizure may occur.

The ideal pressure-charged engine should receive exactly the quantity of air required to provide good combustion of the fuel at all combinations of speed and load, and at present the engine is supplied on each cycle at all loads with a quantity of air which a pressure charger, chosen to suit the maximum load condition, displaces and this results in appreciable wastage of power. Reducing the displacement of the pressure charger would make a big improvement, because the delivery pressure would drop to the limiting condition when the compressor became just a displacing machine with no pressure rise across it. Only the friction and windage losses of the compressor would have to be overcome, resulting in improved fuel consumption, even though the efficiency of the pressure charger must now be zero. Most engines run at light and medium loads for an appreciable part of their lives, so an air displacement control is likely to result in greater fuel economy than a few per cent improvement in the peak overall adiabatic efficiency.

DESCRIPTION OF COMPRESSOR

The construction of the compressor is described with reference to Fig. 1. The casing is of figure-of-eight form and the rotors are hollow cylinders running within this casing and are geared together. On each rotor are two lobes which run within the bore of the casing, and on one side of each lobe is a slot equal in length to the lobe, which allows a lobe on the contra-rotating rotor to pass at each revolution. These slots communicate with the centre bore of the cylinders and are used as ports for the inlet and delivery of air. Ducts in the end plates of the outer casing are arranged to connect with the inner bores of the rotors, and inserted in the bore of each rotor is a tubular valve, which shuts off the port over any desired part of the rotation.

Fig. 2 shows the path of a single charge through one complete cycle. The inlet air is drawn into the compressor through the left-hand rotor, thus filling the spaces between the lobes ; it is divided into two volumes known as the " carry round " volumes, and taken round the periphery of the rotors until the position is reached, when the lobe of the right-hand rotor dips into the pocket of air carried round by the left-hand rotor and direct compression commences. Compression continues to the desired pressure, controlled by the position of the tubular delivery valve, after which delivery takes place. When the delivery is completed the valve closes to stop backflow. It will be noted that the rotor positions 1, 4 and 9 are similar and show the beginning of three cycles during 1½ revolutions of rotation.

DESIGN CONSIDERATIONS

The most important losses in compressors which maintain a clearance space between all working parts is leakage. Because of the rolling action the clearance between the drums may be very small, but a reasonable clearance has to be maintained between the lobes and the casing. The advantage of this design is that this leakage is made to perform a first stage of compression. It can be seen from diagrams 9 to 11 in Fig. 2 that during most of the high pressure part of the cycle the leakage past the lobes enters the carry-round volume of the next cycle, thus raising the pressure. The trapping of this leakage air is triply advantageous, in that it not only performs useful work, but is recompressed and delivered on the next cycle, and is prevented from mixing with the inlet air. Should mixing take place the inlet air would be raised in temperature, thus increasing the work of compression and the delivery temperature.

The displaced volume per revolution per unit length of rotor is approximately the same as that of a Roots type compressor, so speeds at least as high as those used with that type of machine must be contemplated. Thus, if the air inlet and delivery losses are to be kept within reason, very large ports have to be used, and the Bicera compressor allows ample port areas as well as internal compression.

Inlet pressure loss is more important than the delivery loss because it determines the quantity of working fluid handled. The greater the quantity of air passing with the existing losses, the greater the efficiency. In this compressor the air enters through the hub of the inlet rotor and the machine is thus charged to the extent of the centrifugal head developed by the outward flow. The Roots type compressor is poor in this respect, having the inlet air entering against the centrifugal head.

With this compressor it is possible to alter the timing of the rotor ports while the compressor is in operation by having each of the tubular valves fitted with an inner sleeve, which can be rotated to give any desired degree of opening. Such a valve, fitted to the delivery, would control the degree of internal compression before delivery commences or, if fitted in the inlet rotor, would control flow through the compressor.

The effect of altering the length of the inlet period on an ideal machine is shown in Fig. 3. Diagram 1 is for the compressor working with full inlet volume and delivering at the maximum pressure. As the inlet valve is progressively closed the diagrams will change through 2 to 3. These show that if the associated machine requires a constant volume of air from the compressor the delivery pressure will fall as the inlet valve is closed and yet the diagram remains almost ideal in shape without any control of the delivery valve. The conditions of diagram 3 are that the inlet and delivery volumes are equal and, with the internal expansion equal to the internal compression, the delivery pressure is zero.

The advantages of the compressor are :— Internal compression by change in volume of the working space ; degree of internal compression variable ; quantity of air aspirated per cycle variable ; reduced leakage losses for a given clearance ; safe clearance between rotors reduced ; reduced sensitivity of rotor clearance to errors in rotor phasing ; simpler rotor profile ; utilisation of centrifugal force to assist charging.

PROTOTYPE COMPRESSOR

An experimental compressor, much smaller than the minimum size required to give the optimum efficiency, was designed to prove the working principle and to enable a thorough investigation to be made of the occurrences throughout the cycle.

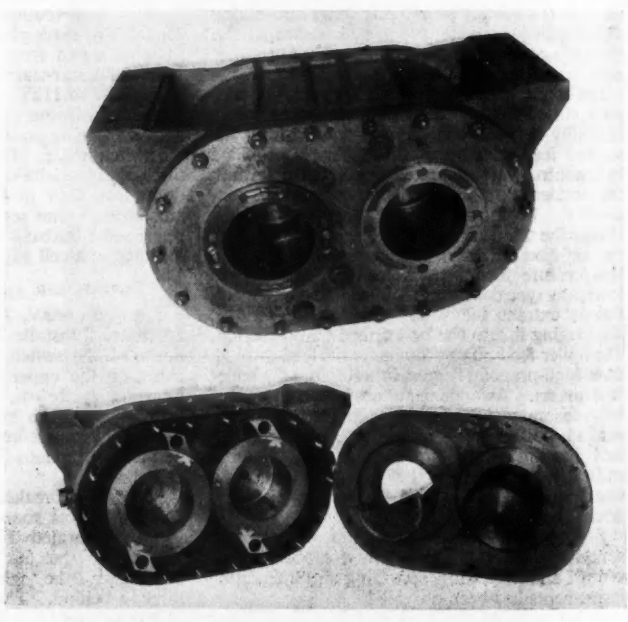


Fig. 1—Components of B.I.C.E.R.A. Compressor

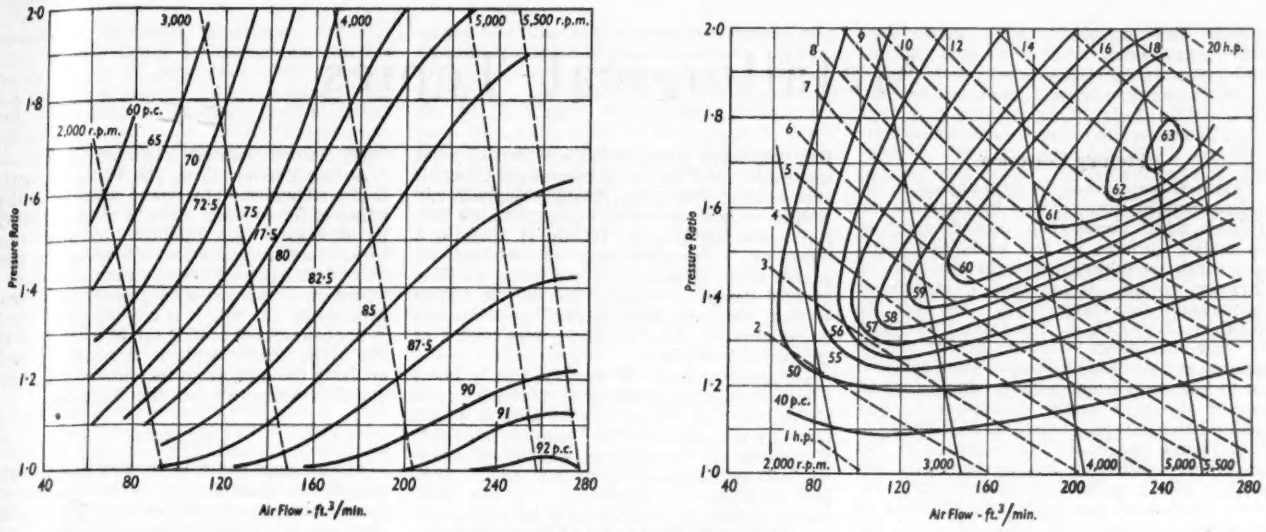


Fig. 2—Performance Characteristic Curves

The brief specification of the compressor is :—

Geometrical displacement	0·0567 cu ft/rev.
Maximum speed	6000 r.p.m.
Maximum speed × displacement	340 cu ft/min
Rotor drums	5·5in diameter
Lobes, two per rotor	0·8in high, 3in long

The compressor was mounted on a test rig and driven through vee belts and pulleys by a petrol engine, and the mounting plate was arranged to pivot about the driving shaft centre line so that the torque input could be measured by a spring balance coupled to an arm of known length. The air inlet and delivery ducts were arranged in position and direction not to effect the torque. Separate tests were made with the compressor coupled to an air meter for air flow measurements.

Fig. 2 shows performance characteristics taken with the delivery valve set at a medium pressure condition, and high efficiencies were maintained over a wide range of pressures and speeds. The delivery valve had 90 deg. of opening for these tests and the delivery port started opening at a volumetric compression ratio of 1·25. This is small because appreciable compression takes place while the valve is opening and compression begins well above atmospheric pressure because of the leakage compression that has already taken place. The value of this leakage recovery is shown by the high volumetric efficiencies obtained. When the internal compression ratio was increased to 1·4 by using a delivery valve with 70 deg. opening the peak efficiency occurred at a higher pressure ratio, and a satisfactory performance was obtained up to 20 lb per square inch gauge delivery pressure. The tests carried out so far include a total of over 300 hours' running, of which 100 hours have been run at a steady 15 lb per square inch gauge delivery pressure.

Variable Displacement Tests

To show the effect of using an inlet valve with an adjustable period of opening, a valve was fitted. To simulate the conditions of a pressure charger supplying a four-stroke cycle engine running at constant speed and variable load, the delivery volume was kept constant by adjusting the inlet volume by means of the variable valve. In the case of a four-stroke cycle compression-ignition engine the air flow would not be reduced below the swept volume of the engine, so there is a lower limit of load beyond which the valve position should be left constant. This load might be of the order of 100 lb per square inch b.m.e.p. for a normal engine and below this load the engine would receive air at atmospheric pressure. There was a large reduction in the power absorbed by the pressure charger as the inlet valve was progressively closed to reduce the delivery pressure to atmospheric and this would result in a considerable improvement in fuel consumption at light loads.

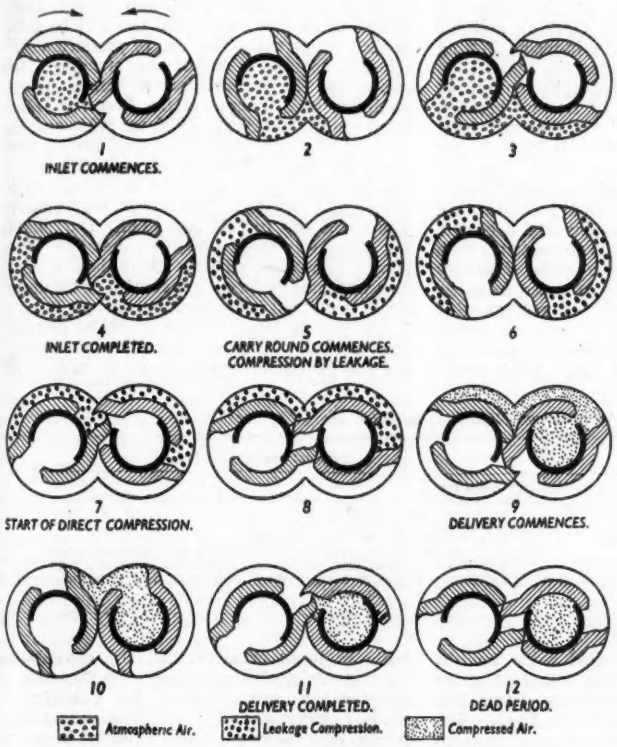


Fig. 3—Two Lobe Compressor Cycle

Apart from the variation of charge pressure with engine load, it is sometimes desirable to vary the pressure with speed, and the natural change is for the charge pressure to decrease as the speed falls. This is suitable for purposes where the torque drops with falling speed, but is unsuitable where an increasing torque with decreasing speed is required. This can be obtained only by increasing the air charge per cycle. To obtain an increasing torque characteristic with a four-stroke engine charged by a Bicera compressor, the governor would be coupled by a linkage to the adjustable inlet valves so that the valve will be held partly closed at full speed and opened as the speed fell. Depending upon the geometry of the linkage, the peak pressure charge condition could be arranged to occur at any engine speed.

A test was made on the compressor under the assumption that it was coupled to a four-stroke engine designed to take a 5 lb per square inch gauge boost at full speed, but capable of working with a higher boost at lower speeds. The initial conditions were set by closing the inlet valve until the delivery was 0·03 cubic feet per revolution at 5 lb per square inch gauge, and this delivery volume was maintained for the whole test regardless of the delivery pressure, by adjustment of the inlet valve. For simplicity, any scavenge during engine valve overlap was neglected. By taking from 6000 r.p.m. to 3000 r.p.m. to open the inlet valve fully the compressor output rose steadily to 10 lb per square inch gauge at 3000 r.p.m. By opening the valve slower with relation to the reduction in speed a constant delivery pressure was maintained down to 1500 r.p.m., or alternatively by opening the valve more quickly the pressure rose rapidly with reducing speed.

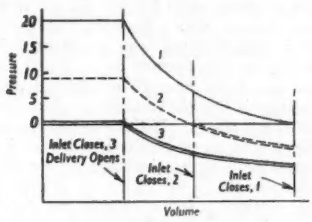


Fig. 4—P/V Diagrams Showing Effect of Change of Inlet Period

These two tests indicate the wide range of new operating conditions which can now be obtained by the aid of this positive variable displacement compressor.

This article has been prepared from a report by D. W. Tryhorn, B.Sc., of the British Internal Combustion Engine Research Association.

T.D.A. Statistical Year Book and Port Analysis.—In order to meet the demand for statistical information, various statistical graphs and tables have been issued periodically by the Timber Development Association. In its *Statistical Year Book* for 1951 the Association has now presented this material within the covers of a book. The figures given include U.K. imports, production, consumption and stocks of timber for a number of years, together with summaries showing the value of all U.K. imports for 1949–51. These facts are illustrated in a series of seventeen tables, for easy reference. Copies of the *Statistical Year Book* may be obtained on application to the Timber Development Association, 21, College Hill, London, E.C.4, at a cost of 2s. 6d. each. The second edition of an analysis, entitled "United KingdomTimber Imports: Port Analysis," has also been published by the Association. In this two-page chart every port in the country handling timber is listed. It is obtainable from the Association, at a cost of 6d.; if ordered as an addendum to the *Statistical Year Book* there is no charge.

Metallurgical Topics

Fretting Corrosion

FRETTING corrosion is the term applied to the surface damage, accompanied by accumulation of debris, which occurs at the area of contact of the mating surfaces of two well-fitting metal parts which are subjected to slight oscillatory or vibratory motion. It has been a well-known phenomenon for many years. The first to investigate it was G. A. Tomlinson,[1] who held the view that direct oxidation of the surface occurred as a result of the breakdown of cohesion due to high local temperature produced over an area of almost molecular dimensions by very small relative motion. Later, G. A. Tomlinson, P. L. Thorne and H. J. Gough[2] concluded that the primary cause of fretting corrosion was attrition of the surfaces on a molecular scale, and in the case of steel subsequent oxidation of the debris. On the other hand, M. Fink[3] put forward the explanation that fretting corrosion was due to surface irregularities undergoing plastic deformation which renders these areas very active chemically, and that by repeated rubbing away of the oxide film which forms at these positions and would normally retard further attack, fresh metal is always being exposed to oxidation and the attack continues to proceed at a rapid rate.

A.S.T.M. Symposium

On June 25, 1952, a symposium on "Fretting Corrosion" was held under the auspices of the American Society for Testing Materials, at which five papers on different aspects of the subject were read and a film shown. W. E. Campbell, in a paper entitled "The Present Status of Fretting Wear," expressed the view that the oscillatory relative movement must be of sufficient amplitude to cause "gross slip" between the contacting surfaces; that fretting was accelerated by the abrasive oxide film formed as a result of wear; and that the only measure which will eliminate wear entirely is the elimination of the gross slip between the surfaces. If this cannot be done by reducing amplitude of oscillation, it may be done by interposing between the surfaces a material of high enough shear elasticity to prevent gross relative motion. In a paper on "Fretting Corrosion Tendencies of Several Combinations of Materials," J. R. McDowell, of the Westinghouse Research Laboratories, described the behaviour of a large number of combinations subject to conditions producing fretting corrosion. All rigid materials were found to give an oxide debris or to be affected by a fretting action which roughened the surface. Some non-metals were worse than metals. Dry lubricants only delayed the onset of fretting, but fitting a rubber gasket between the vibrating surfaces (when this was possible) completely stopped the action. O. J. Horger discussed "Fretting Corrosion in Fitted Members" in relation to reduction in fatigue strength. He found that fretting action led to the initiation of fatigue cracks in clamped, press- or shrunk-fitted members subjected to vibratory stresses. This might occur at very low fluctuating stresses—often within good design limits—and might necessitate frequent renewal of the parts. In a paper on "The Effect of Lubricants in Minimising Fretting Corrosion," E. W. Herbeck, jun., and R. F. Strohecker pointed out that investigators differed as to the corrective effect of various lubricants. As a result of trials of different grades of lubricant, they considered that "feedability" was of prime importance and that soap bases, solid materials such as zinc oxide or molybdenum sulphide, and additions such as tri-cresyl phosphate do not, *per se*, alleviate fretting. Finally, H. Uhlig, in a paper on "The Mechanism of Fretting," reported results of tests made in a testing machine of new design, in which load on the fretted surface, total slip, frequency of vibration and composition of the atmosphere were treated as independent variables.

Douglas Godfrey, of the N.A.C.A.'s Lewis Flight Propulsion Laboratory, Cleveland, who showed the film, stated that the purpose of the research instituted by the National Advisory Committee for Aeronautics was to determine the basic mechanism of the process and to investigate principles of mitigation. The film illustrated susceptible surfaces in a jet engine and fretted bearings, as well as colour motion photomicrographs of fretting action between steel and glass, and between ruby and glass. The research indicated that fretting is due to the loosening of finely divided, apparently virgin, material which is extruded from the contact areas and reacts with oxygen simultaneously. Fretting may thus generally be considered as a form of concentrated and severe wear.

The Subject Reviewed

In view of the continued importance of eliminating fretting corrosion and the recent interest in the subject, attention may be directed to a timely review, "Fretting Corrosion—What It is, Its Cause and Possible Preventives," by A. H. Allen.[4] Although mention is made of work by B. W. Sakmann and B. G. Rightmire, who concluded that chemical action is of primary importance, the main part of the review is devoted to the work of D. Godfrey and his associates. The apparatus for inducing fretting corrosion in specimens under the microscope is described and photomicrographs reproduced showing progressive stages of fretting between glass microscope slides and ¼in diameter balls of S.A.E. 52100 steel (carbon 0·95–1·10 per cent, chromium 1·20–1·50 per cent). The first indication of fretting came within a quarter second (30 cycles) in the form of a small black spot on the ball. The spot grew steadily and a brown, sticky oxide began to share the contact area with the black material. A rust-coloured, fine, dry oxide was also formed, being extruded from the area in increasing quantities and accumulating at the edges. After about 40,000 cycles the action stabilised to a steady growth with continued generation of material in the black spots surrounded by brown semi-fluid oxide and the fine powder oxide. The black colour indicated finely divided iron. The fretting debris was identified by electron diffraction as Fe_3O_4. The colour changes that occurred pointed to the progressive oxidation of the iron. Oxide formation was induced at extremely low speeds and light loads, dissipation of heat being fast enough to rule out the occurrence of local hot spots. It is thus unlikely that fretting is caused by rubbing off a regenerative oxide film. The fact that oxidation is not a primary cause was shown by a test in which clean platinum foil, supported by a steel ball, was vibrated in contact with clean glass. Black powder was generated in the usual way, though the metal will not, of course, oxidise in air. The black powder was identified as finely divided platinum (platinum black).

As remedial measures, the N.A.C.A. investigators recommend any means whereby the high adhesive forces which remove virgin metal can be decreased, for example, by maintaining between the surfaces a film of low shear strength. The effectiveness of molybdenum disulphide as an inhibitor appears to be promising, but much depends on the way it is applied (see Table I). A bonded form of coating can be made by mixing the MoS_2 powder with a resin-forming liquid, applying the mixture to the cleaned metal parts and then curing to a dry, thin, hard film.

Conclusion

The evidence points to the fact that fretting is caused, not by oxidation, but by the loosening, due to inherent adhesive forces, of finely divided and evidently virgin material. On most metals this material will oxidise rapidly as it is extruded from the contact area. Thus, all the new evidence supports the view put forward in 1939 by Tomlinson, Thorne and Gough that the primary cause of fretting corrosion is of a mechanical rather than a chemical nature.

References

[1] *Proc. Roy. Soc.*, 1927, Vol. A115, page 472.
[2] *Proc. I.Mech.E.*, 1939, Vol. 141, page 223.
[3] *Trans. Am. Soc. Steel Treating*, 1930, Vol. 18, page 1026.
[4] *Metal Progress*, December, 1952, page 71.

Molybdenum-Rich and Tungsten-Rich Coatings on Steel

THE measure of success which has attended the development of chromising and siliconising of steel encourages the hope that similar diffusion coatings of the rarer metals may become available in order that economical use may be made of their properties. The idea of producing such diffusion coatings is one of long standing. The papers on the cementation of ferrous alloys, published by J. Laissus in the *Revue de Métallurgie* during the years 1926 to 1928, and the work of G. Grube during the same period, foreshadowed the possibilities of producing useful coatings of a variety of metals including molybdenum and tungsten. The process was cementation at 900 deg. to 1200 deg. Cent. The cementing agent was finely powdered metal or ferro-alloy. The cemented zone diminished in thickness with increase in carbon content of the underlying steel, and with medium carbon steels a bright surface layer, probably rich in carbides, was formed. In producing diffusion coatings the use of gaseous atmospheres or molten salt baths is more effective than the cementation methods originally proposed. In the case of molybdenum and tungsten, for example, F. Halla, L. Egartner and R. Weil* found that when Armco iron specimens were suspended in molten sodium molybdate or sodium tungstate, maintained at 1000 deg. Cent. in an atmosphere of hydrogen or of ammonia, reduction took place at the metal surface, followed by diffusion of the metal deposited forming a surface layer of iron-molybdenum or iron-tungsten alloy.

The diffusion process has been studied by E. Fitzer† whose results enable a forecast to be made of the depth of penetration under various

TABLE I.—*Fretting Corrosion Tests with Molybdenum Disulphide Inhibitor*

Surface condition	Steel ball against glass flat		Steel flat against steel ball	
	Cycles for first corrosion	Condition of contact area after test	Cycles for first corrosion	Condition of contact area after test
Clean	1 to 30	Instantaneous fretting	Less than 100	Immediate fretting
MoS_2; dusted	72,000	MoS_2 formed smooth bearing surface then rubbed away...	100,000 to 160,000	Dry red oxide and stain
MoS_2 and oil; immersed	86,400	MoS_2 visible only in surrounding area	700,000 to 760,000	Brown-black debris and spotty surface failure and stain
MoS_2 and grease; coated	216,000	MoS_2 visible only in surrounding area	1,500,000	Brown-black debris and spotty surface failure and stain
MoS_2 and syrup; bonded	28,000,000	Coating formed smooth bearing surface, then brown stain appeared	9,850,000	Smooth shiny bearing areas formed, then brown powder appeared

* *Monatsch. Chem.*, 1948, Vol. 78, page 155.
† *Archiv Eisenhüttenw.*, 1952, Vol. 23, pages 363 and 369.

conditions. He found, as Laissus had also found for cementation by ferro-alloys, that the greatest depths of penetration were obtained with the lowest possible carbon content in the steel. The surface layers never reached a very high alloy content. In Halla's experiments, after 150 hours' immersion in the appropriate salt bath at 1000 deg. Cent., the average alloy contents to a depth of 0·06mm were just over 12 per cent of molybdenum and just under 11 per cent of tungsten respectively. A layer of similar depth after twenty-four hours in the salt bath at 1100 deg. Cent. contained 5 to 7 per cent of tungsten or of molybdenum. These amounts are insufficient to raise the melting point of iron, so no beneficial effect of the high melting points of molybdenum and of tungsten can be looked for in the surface layers. The surfaces, however, as well as the underlying steel, could be gas carburised to give increased resistance to wear. The surface hardness of the molybdenised layer was about 120, and this was raised, by gas carburising in a mixture of hydrogen and 8 per cent propane-butane for ten hours at 960 deg. Cent., to 350 in the annealed condition and to 1200 (Vickers diamond hardness) when quenched. A similar hardness of over 1200 was obtained by nitriding molybdenum-coated electrolytic iron for twenty to thirty hours at 540 deg. Cent. This hardness showed a stability to tempering up to 500 deg. Cent., but was reduced to about 250 by annealing at 900 deg. Cent. Simultaneous molybdenising and nitriding by the use of ammonia in the molten bath is not possible, but there may be a possibility of coupling both processes in the same apparatus. Fitzer expresses the opinion that the method is only likely to be applicable to small components.

In view of the poor resistance of molybdenum to oxidation at high temperatures it may be important to note that the molybdenised layer may be siliconised by treatment in silicon tetrachloride at about 1100 deg. Cent. with the formation of an iron-molybdenum-silicide intermediate layer which, in spite of fissures in the outer layer, forms a protective surface for the core of metal.

Titanium and Titanium Alloys

THERE has probably never been so much public interest in a new metal as is now shown in titanium, and the development of no other metal has been responsible for such a number of papers as have appeared in technical journals during the past five years. The subject of "Titanium and Titanium Alloys" is reported to have drawn a record attendance last autumn at a symposium organised by the Institute of Metals Division of the American Institute of Mining and Metallurgical Engineers.[1] Representatives of the American Army, Navy and Air Force discussed possible uses of titanium, particularly for weight saving in military and airborne equipment, and R. S. Dean, for many years chief metallurgist at the U.S. Bureau of Mines, where the Kroll process was developed, described the processes of production. Nearly all ductile titanium is now produced by the Kroll process (reduction of the tetrachloride by magnesium) and a little by the van Arkel method (thermal reduction of titanium tetraiodide). Mr. Dean suggested some possibilities of new processes, including the reduction of the lower chloride, titanium dichloride, the reduction of titanium dioxide by calcium, and the electrolytic reduction of titanium salts dissolved in a molten bath of alkaline chlorides. The last two methods were investigated many years ago and were abandoned in favour of the present processes, but more recently development of an electrolytic process has received much attention in the University of Melbourne, Australia. The afternoon session was devoted to questions of production and supply. Representatives of producers were inclined to measure progress by their success in making bigger and bigger ingots of titanium. Success of these commercial operations is made possible largely by the subsidies of the U.S. Defence Department, but the methods employed are inherently expensive and simply to multiply the plant, though giving increased production, is not likely to reduce the cost of the product. All the speakers representing user interests agreed that reduction of cost was essential, and that full realisation of the advantages of titanium must depend on the solving of certain production problems. The chairman of the symposium, Dr. M. A. Hunter, whose interest in titanium dates from 1906, when, as an investigator in the G.E.C. research laboratory, he was the first to prepare titanium for possible use as electric light filaments, emphasised the need for radically new methods and recalled that there was usually a lapse of a decade from research on a new method to tonnage production.

At the exhibition held in connection with the same meeting, titanium metal was on view in many forms ranging from 2-ton ingots to small forgings, thin sheet and fine wire. It is clear that the scale of production already achieved has made possible some minor applications, and is affording potential users the opportunity of making a thorough test of their ideas on a working scale. If its cost could be greatly reduced, many uses could be found for a metal offering the advantages of low density (4·5), high melting point (1725 deg. Cent.), good tensile strength, high resistance to atmospheric corrosion, to sea water attack, and to many corroding media. Its useful properties at room temperature and high melting point encourage the hope that its high temperature properties will fill the gap between those of aluminium alloys and of steel. One limitation is that at elevated temperatures it will rapidly absorb oxygen ; but it may be held at temperatures up to 425 deg. Cent. in air without deterioration, and annealing of the cold-worked metal can be carried out rapidly in air at temperatures like 700 deg. Cent.

An ultimate object of much of the planned research is to make titanium a useful and available material of construction, particularly for aircraft, but for the replacement of aluminium alloys or stainless steel in this application, the strength of pure metallic titanium is not sufficient to give an adequate strength/weight ratio. The strength of annealed titanium sheet is less than half that required, and in the cold-worked condition with the disadvantage of very low ductility, it falls short of requirements by about 20 tons per square inch. It should, however, be possible to produce titanium-base alloys with a density of not more than 5 and a tensile strength of 75 to 80 tons per square inch with little loss at aerodynamic friction temperatures ; and a large number of alloy systems have been investigated to explore their possibilities. It is difficult, however, in view of the rapidly accumulating mass

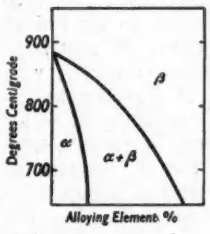


Fig. 1—Typical Diagram of Useful Titanium-Base Alloys

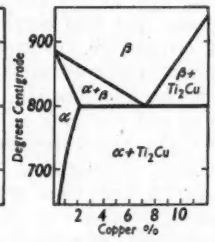


Fig. 2—Diagram of Titanium-Copper Alloys

and variety of data about alloys of different compositions, for the onlooker to be sure of the direction in which greatest progress is to be expected. A simplification of the complexities of titanium-base alloys is provided in an article entitled "The A B C of Titanium Alloys," by W. L. Finlay, C. I. Bradford and G. T. Fraser.[2] Titanium exists in two allotropic modifications: alpha, having a hexagonal close-packed structure stable up to about 885 deg. Cent., and beta, with a body-centred cubic structure stable from that temperature up to the melting point. The transition temperature is affected by alloying additions, and, according to Finlay, Bradford and Fraser, the alloys which are most likely to be useful belong to systems of the kind shown in Fig. 1, in which the added element forms a series of solid solutions with titanium and extends the range of stability of the beta solid solution down to room temperature. The elements carbon, oxygen, nitrogen and aluminium widen the alpha field ; and hydrogen, manganese, chromium, molybdenum, iron, vanadium, and niobium stabilise beta to a lower temperature. With some of these elements in large amounts a third phase is introduced, causing damaging embrittlement. A system which shows intermetallic compounds with formation of a eutectoid, as, for example, titanium-copper (Fig. 2), is not likely to give useful alloys ; increased strength is offset by almost complete lack of ductility.

The characteristics of the different structural types of titanium alloys can be summed up as follows :—

Alpha Alloys: Resist oxidation, good weldability, useful strength up to 650 deg. Cent., no response to heat-treatment, bend ductility not so good as alpha-beta and require more power for hot working.

Alpha+Beta Alloys: Moderate resistance to contamination, good bend ductility, but poorer weld ductility than alpha, respond to heat-treatment which needs careful control to avoid loss of ductility, weaker than alpha or beta above 200 deg. Cent., lower creep strength, limit of useful strength 425 deg. Cent., forging, rolling and forming easier than for alpha or beta.

Unstable Beta Alloys (i.e. beta retained by air cooling, but broken down with accompanying embrittlement, on heating at temperatures between 180 deg. and 420 deg. Cent.) : Heat treatable by quenching and tempering to give high tensile strength with some loss of ductility, control of composition and treatment critical, high temperature properties similar to those of alpha+beta, restricted to parts that can be heat treated after fabrication.

Stable Beta Alloys : Sensitive to contamination during production, especially in air above 700 deg. Cent., excellent bend ductility, good weldability, no response to heat-treatment, limit of useful strength 550 deg. Cent., have higher alloy content and therefore higher density.

Stable beta alloys, e.g. titanium with over 30 per cent molybdenum, are excluded on account of their high density and high content of strategic elements ; unstable beta alloys are exemplified by 85 per cent titanium plus 15 per cent of manganese, chromium, molybdenum, or iron. A typical all-alpha alloy is titanium-aluminium. Industrial activity has been almost entirely confined to the alpha+beta alloys. These have an alloy content of about 3 to 9 per cent of a beta stabilising element, and are already established as the type from which structural titanium alloys

TABLE I.—*Properties of Alpha+Beta Alloys of Titanium*

	Ti sheet	92 : 8 Ti-Mn sheet	92 : 4 : 4 Ti-Mn-Al rolled bar
Proportional limit, tons per sq. in.	22	42	47
Yield strength, tons per sq. in. ...	29	51	62
Ultimate tensile strength, tons per sq. in.	33	58	67
Elongation, per cent	25	15	18
Reduction of area, per cent... ...	—	—	40
Bend ductility (Times thickness)	1·5	2·0	2·0

will be developed. Two examples are given in Table I, the 92 : 8 titanium-manganese and the alpha-strengthened 92 : 4 : 4 titanium-manganese-aluminium alloy compared with commercially pure titanium.

According to the authors of the review quoted, there are fairly clear indications of the course of future progress, but in spite of the active work of many investigators the most promising alloys have not yet been finally selected and their properties and behaviour adequately determined.

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[1] *Journal of Metals*, December, 1952, page 1346 ; *Metal Progress*, December, 1952, page 70.
[2] *Metal Progress*, November, 1952, page 73.

PLASTICS MOULDING PRODUCTIVITY REPORT.—The Plastics Moulding Productivity Report, which sets out the findings of the team which visited the U.S.A. early in 1952 will be published on Monday, February 16th. The first public meeting to discuss the report will be held on March 4th, in the Conference Room at the offices of the British Plastics Federation, 47–48, Piccadilly, London, W.1, at 2.30 p.m., and the productivity team will be present. In order that arrangements may be made, it will be appreciated if those who wish to attend would notify the British Plastics Federation well in advance. Other public meetings are being arranged in Birmingham and Manchester towards the end of March, details of which will be announced.

THE ENGINEER

Vol. 195 JANUARY 30, 1953 No. 5062

LEADING ARTICLES—
Royal Electrical and Mechanical Engineers ... 174
" Just So " or " Near Enough " 174

ARTICLES—
Administrative Costs of Gas and Electricity Boards 157
American Symposium on Heavy Presses 183
Asian Coal and Iron Ore Resources 182
Atomic Power 157
Bankside Power Station. No. II. (Illus.) ... 167
Corrosion Resistance of an Aluminium Coating 188
Design of Precision Grinding Machines 177
Elizabeth River Crossing. (Illus.) 178
" Empress of Canada " 157
" EUSEC " Conference on Engineering Education 182
First Iron Steamer. (Illus.) 163
Guided Rockets 157
James Watt International Medal 157
Lloyd's Shipbuilding Returns 166
National Research Development Corporation Report 176
Plastic Mouldable Refractory 162
Productivity Team Report on Machine Tools ... 185
Reconstruction of Skipton Engine Sheds 182
Research and the Gas Turbine. (Illus.) 186
Rotary Compressor with Inbuilt Compression. (Illus.) 170
Sewage-Sludge Digestion Calculations. No. I. (Illus.) 158
Some Foreign Civil Engineering Schemes of 1952. No. I. (Illus.) 164
Welding in Marine Engineering. No. II. (Illus.) 160
William Froude Memorial 157

METALLURGICAL TOPICS—
Fretting Corrosion 172
Molybdenum-Rich and Tungsten-Rich Coatings on Steel 172
Titanium and Titanium Alloys. (Illus.) 173

LETTERS TO THE EDITOR—
Melting Point of Chromium 176
Simplicity in Gears 176
Ode to a Transposition 176

LITERATURE—
Books Received 176

OBITUARY—
Brigadier-General Magnus Mowat, C.B.E. ... 175
Rhys Jenkins 176
H. Pelham Lee 176

NEWS AND NOTES—
Books of Reference 182
British Patent Specifications. (Illus.) 191
Contracts 192
Forthcoming Engagements 192
Industrial and Labour Notes 189
Launches and Trial Trips 192
Notes and Memoranda 190
Personal and Business 190

THE ROYAL ELECTRICAL AND MECHANICAL ENGINEERS

The Corps of Royal Electrical and Mechanical Engineers is just over ten years old—young enough to be well aware of its " growing pains," yet old enough, halfway to its coming-of-age, to justify a glance backwards over its short but eventful history. R.E.M.E., it may be recalled, came into being, in 1942, in the heat and stress of war, in an effort to conserve manpower and eliminate duplication by undertaking the repair of a variety of technical equipment hitherto the responsibility of a number of individual Corps, notably the Royal Engineers R.A.O.C. and R.A.S.C. The intention was that R.E.M.E. was ultimately to take over the repair of all the Army's technical equipment. It was natural that changes of this magnitude should be carried out in stages and it was to be expected, particularly in wartime, that not all the stages could be described as " easy," for many of them involved the large-scale transfer not only of functions but of personnel and workshop equipment as well. Much of the reorganisation has been carried out since the end of the war in 1945 and, as a result of the later stages in the process, in 1951 and 1952, R.E.M.E. absorbed the remaining R.A.S.C. workshop personnel and unit tradesmen in the R.A.C., Royal Artillery and infantry. Briefly, then, the function of R.E.M.E. is to ensure that Army equipment is kept in " battleworthy " condition and it discharges its task by carrying out the inspection, recovery and repair of all the Army's mechanical and electrical equipment. It is a heavy commitment—heavy because of the numbers involved and because of the variety and complexity of much of the equipment, which ranges from 15in coast defence artillery and anti-aircraft radar equipment on one hand, to pistols and telephones on the other. With such a commitment at a time when manpower is scarce it is not surprising that R.E.M.E. should be closely preoccupied with the problems of training. Some of these problems and the way they are being tackled were effectively demonstrated at a recent Press visit to the R.E.M.E. Training Centre at Arborfield and Bordon.

For functional training purposes the establishment comprises four training battalions : two, at Arborfield, are concerned with telecommunications and radar respectively, and two, at Bordon, with armament and vehicles. Each battalion is thus specialist in the technical sense, but each is concerned with the training of the same classes or grades of craftsmen and of officers. Broadly speaking the bulk of the training effort is devoted to craftsmen who are graded, according to skill and experience, into three classes and who correspond to the artisan in civilian life. Numerically the next large group comprises armament artificers, who combine the functions of first-class tradesmen with the rank and authority of senior N.C.O.s and correspond to foremen-technicians in a factory. Finally, there is the smallest and most important group, consisting of officers who have the qualifications and status of professional engineers. This over-simplified picture of the set-up suggests that the methods of technical training will be akin to those of the engineering industries. The main difference is that the civilian engineer and artisan are partly, perhaps mainly, engaged in developing, designing and making things while the R.E.M.E. craftsman is concerned solely with their maintenance and repair. It is perhaps no more than a subtle distinction, for the aim is merely to ensure that, provided the trainee has the necessary theoretical background, manual dexterity and flair for " trouble-shooting," he should not be disqualified by the setting of too high a standard of mathematical ability. On the other hand, for men who will have to service radar equipments or fire control servo-mechanisms, and soon, perhaps, guided missiles, the standard must of necessity be high. For example, the aim is that armament artificers (electronic control equipment) should be trained, academically, to Higher National Certificate standard at least. But the main difficulty that confronts R.E.M.E. is primarily one of recruiting rather than of training *per se*, and it is a corollary of full employment. The immediate shortage is less acute at trainee-craftsmen level, where the National Service intake provides the bulk of the raw material. It is at the higher levels that there is a serious lack of sufficient skilled men, for the period of National Service ends just when the best of the officers and the potential armament artificers are reaching their maximum usefulness to the Corps. Then, unless they can be induced to undertake a regular term, all their specialised training and abilities are lost to the Service.

Until the Army can offer higher inducements, such as improved amenities for the married man and his family, with some prospect of a settled existence, it is likely that the time-expired National Serviceman will find it hard to resist the attractions of a return to civilian life. Much the same considerations no doubt apply to the direct recruitment of regulars, the tradesmen and potential N.C.O.s who will form the backbone of the Corps. But unfortunately it is easier to diagnose the malady than to prescribe the remedy at a time when there are so many demands on national resources generally and housing in particular. With officers there is, perhaps, a wider field for recruitment, apart from the National Service element. For a regular commission in R.E.M.E. offers an attractive career to young men leaving school and entering the Royal Military Academy, Sandhurst, after about six months' normal military training or to university graduates with an engineering or science degree. In the last analysis, however, R.E.M.E. will win its best recruits from amongst those who seek an interesting and adventurous career, with an emphasis on service. If, as many believe, it is *esprit-de-corps* that attracts recruits, and if the spirit that animates the R.E.M.E. Training Centre is typical of the Corps as a whole, then there should be no lack of quality to make up for lack of numbers.

" JUST SO " OR " NEAR ENOUGH "

In the practice of engineering there are now two schools of thought. Upon the one hand there are the fine craftsmen who can never be satisfied unless everything is " just so," to whom it is part of the fitness of things that inward perfection should be outwardly expressed by high finish and who are not content unless what they make is as exactly fitted to perform its functions as they can make it. Upon the other are those who consider it a waste of time, money and labour to make anything more accurately than " near enough " to do its job satisfactorily, to whom outward appearance means little and who maintain that so long as a product is approximately fitted to perform its function the user can be compensated for any slight inconvenience by the offer of a much lower price. The consequences of following those two lines of thought are oddly contrasted when the machine tool industry is compared with the automobile industry, which owes so much of its success to the highly productive machine

tools that have been supplied to it. In the latter, through the adoption of standardisation, simplification and specialisation—all processes by which products " near enough " to the ideal are used—productivity has been pressed to great heights, wages have risen and the price of the product, which has attained increasingly high standards of quality and reliability, has tended to fall. But in the machine tool industry, in which, both in Britain and America, a large number of predominantly small firms continue to go their individualistic ways, largely eschewing standardisation and simplification, productivity has not greatly risen. In consequence rising wages, necessitated by the need to prevent workers being drawn away to the automobile factories, have led to higher prices. That is the contrast to which an Anglo-American productivity team report on machine tools, issued last Monday, draws attention.

The majority of those who compiled the report seem to have been numbered amongst the high productivity, " near enough " school. As a consequence a decidedly controversial document has been produced, of some sections of which not all the members of the team approve. The criticisms expressed are directed not only at the British machine tool industry but at the American industry as well. For the team found little to choose between them. Many of these criticisms are also applicable to other industries. They are, indeed, quite familiar in their application to them. Since long before the war production engineers have been criticising the tendency of draughtsmen and designers to specify unnecessarily accurate limits and fits and to call for unnecessarily high finish. Nor has the desirability of designing specifically for ease and cheapness of production escaped notice. But there are other ideas in the report that are more novel. There is a reference, for instance, to one American concern which is having many of its drawings made freehand on squared paper and not necessarily even approximately accurate, the drawing itself being conceived merely as " a method of indicating dimensions in the correct relationship one to another, or of the position of components as units relative to one another in an assembly." There is, too, a well-expressed discussion of the old point that the majority of general purpose machine tools are made to-day to serve a very wide range of purposes but that once installed by the user they tend to be used only for a narrow range of work. How often, we wonder, are screw-cutting attachments on centre lathes ever used ? And how often is the full range of speeds and feeds built into a machine really necessary for the jobs it will be called upon to do ? The report goes further. Is all the accuracy put into the machines really necessary ? Some 21 per cent of all the machine tools in America are believed to be more than twenty years old and another 22 per cent between ten and twenty years old. " Most of these relatively inaccurate machines are presumably doing their jobs satisfactorily as far as the accuracy of the product is concerned. Was the original accuracy worth the cost of achieving it ?" Finally, the concept is studied that a machine tool is fundamentally the combination of a rotating movement with a linear movement—leading to the suggestion that ranges of standard spindles, housings, drive units, slides, feed units, columns, bases, &c., should be developed, from which machines, special or standard, could be built up for almost any purpose and much more cheaply than at present.

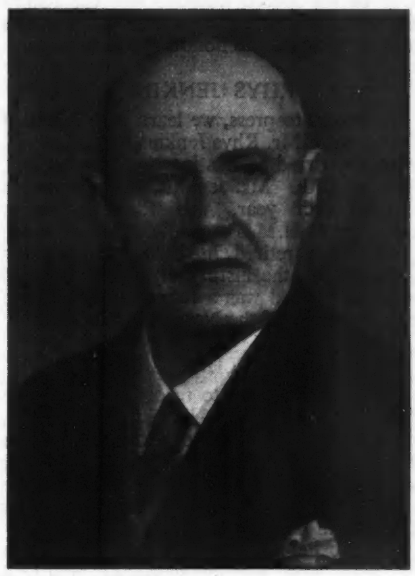
It is not our purpose here to discuss in any detail the various recommendations and proposals in the report. But there do seem to be some remarks that should be made. First and foremost, should not a distinction be drawn between machine tools made for the production floor and those for use in the tool-room ? The recommendations of the team, which we print elsewhere in this issue, might perhaps be profitably applied to production tools. But it is difficult to see them being applied to the tools of particularly high quality needed in a tool-room, tools that may be used for any purpose within their range to make articles to the highest possible standards of accuracy. These tools must continue to be made by craftsmen who will not tolerate anything that is not " just so " and the men who make them and use them, managers as well as skilled workers, are likely to be psychologically incapable of failing to provide or desire an outward finish that expresses the inward perfection of the machine. There is every reason why such tools should continue to be made by those numbers of small firms which take a high pride in the quality of design and workmanship that goes into their products and which, because they operate on a small scale, are able, if requested, to build tools, tailor-made to customers' requirements, and to try out new ideas and evolve improvements. As for the making of " production " tools from standardised units we are left wondering whether it could be commercially successful. The basic conception in the report is that a substantial reduction in price would lead, as it has in the automobile and many other industries, to a greatly expanded demand. But is there much truth in that idea ? Save in the sense that rapidity of replacement affects it, the demand for machine tools is dictated rather by the demand for the products made by the tools, than by the price of the tools themselves. Nor do we think the price of the tools enters at all largely in most industries into the price of the products made by them. Under these circumstances is it not possible that a manufacturer, offered a choice of a relatively cheap (though admittedly effective) " utility " article or a dearer, more accurate and well-finished machine, would choose the latter ? For there is an old saying that the best is cheapest in the long run. Undoubtedly, as in other British industries, there is scope for more standardisation, specialisation and simplification in the machine tool industry. It is even possible that progress is being retarded, as is suggested in the report, by a kind of in-breeding, the consequence of the men in the industry trained in it being and spending their whole lives in it without experience outside. But whether these processes could profitably be carried as far as is proposed in the report is quite another matter. Nor is it a matter that machine tool makers alone should discuss. Users of machine tools might profitably discuss it too.

Obituary

BRIGADIER-GENERAL MAGNUS MOWAT, C.B.E.

As briefly recorded in our last issue, the death occurred suddenly, on January 19th, of Brigadier-General Magnus Mowat, C.B.E., M.I.Mech.E., of Ebor House, East Sheen, S.W.14. General Mowat, who was seventy-seven, was for eighteen years secretary to the Institution of Mechanical Engineers, and was well known not only to the members of that Institution, but also to many other engineers at home and abroad.

Magnus Mowat, who was born on November 10, 1875, was the son of the late Honourable Magnus Mowat. He was educated at Aberdeen Grammar School, Blackheath School, and King's College, London, and served an apprenticeship in the North British Railway Works at Cowlairs, under the late Mr. M. Holmes, the locomotive superintendent. For a few years at the beginning of his professional career, General Mowat was engaged in railway work, first as



Brigadier-General Magnus Mowat

an engineering assistant on the Leicester section of the Great Central Railway and subsequently, from 1899 to 1901, as assistant engineer on the Indian Midland (later G.I.P.) Railway. He returned to this country in 1901 and took up an appointment, with Robert McAlpine and Sons, Ltd., as contractors' engineer on the Partick section of the Glasgow main drainage system. A year later General Mowat became assistant engineer of the Millwall Dock Company, Ltd., and in 1905 he succeeded to the position of chief engineer and general manager of that company. Subsequently, he had charge of the East and West India Docks and the Millwall section of the London Docks under the Port of London Authority. During the first world war General Mowat commanded a division of the Royal Engineers for two years or so, and was then appointed Commands Road Officer and Director at the War Office. In recognition of his war services he was created C.B.E. in 1919.

In October, 1920, following the retirement of Mr. Edgar Worthington, General Mowat was appointed secretary of the Institution of Mechanical Engineers, an office which he very ably occupied for the next eighteen years. During those years the work of the Institution developed considerably in many directions. The number and the activity

of its local branches increased, and in 1930 the Royal Charter of Incorporation was granted. By that time the membership of the Institution exceeded 10,000. Following a serious illness in 1938, General Mowat felt obliged to relinquish the secretaryship of the Institution, and as a mark of the esteem in which he was held by all grades of membership, the Council conferred upon him the title of honorary secretary. During his years at Storey's Gate, General Mowat gave unstinted service to the "Mechanicals," of which he had become an associate member in 1902 and a member in 1905. He was also a member of the Institution of Civil Engineers, a member of the Institution of Engineers and Shipbuilders in Scotland, a Fellow of the Chartered Institute of Secretaries, and a Fellow of the Royal Society of Edinburgh. To the end, General Mowat kept up an active interest in all matters concerned with the engineering profession, and in particular with engineering education. He was a member of the council of King's College, London, and of the councils of the Battersea Polytechnic and the Wandsworth Technical Institute. One of his special interests was the King's College Engineering Society, of which he was a past-president and honorary life member.

RHYS JENKINS

As we go to press, we learn with regret of the death of Mr. Rhys Jenkins, M.I.Mech.E., which occurred at Hastings on Tuesday last, January 27th. Mr. Jenkins, who was in his ninety-fourth year, was formerly senior examiner at H.M. Patent Office, from which position he retired in 1920. He was an authority on the history of engineering and technology, and was a founder-member and past-president of the Newcomen Society.

H. PELHAM LEE

WE regret to have to record the death, on January 22nd, of Mr. Horace Pelham Lee, chairman and founder of Coventry Climax Engines, Ltd., Coventry. Mr. Pelham Lee will be remembered by many engineers as one of the pioneers of this country's motor-car industry in the early years of this century.

Horace Pelham Lee was born in London in 1877, and was educated at Bradfield College. Following some electrical engineering training, he became a pupil at the works of W. H. Allen, Sons and Co., Ltd., Bedford, and upon the completion of his pupilage he was on active service in the Boer War. After that war Mr. Lee worked for a period in the factory of the Daimler Company, and in 1903 he took some premises in East Street, Coventry, where he started business as a motor-car manufacturer under the name of Lee, Stroyer. The capital required for motor manufacturing, however, was more than was available, and the company therefore concentrated on the production of engines. But one of the few cars that were made in these works was successfully used by Mr. Pelham Lee to demonstrate his engines. In 1914 the Lee, Stroyer Company provided engines for the tractors for Sir Ernest Shackleton's expedition, and during the first world war the company received contracts for generating sets used for searchlights.

In 1917 Mr. Pelham Lee formed Coventry Climax Engines, Ltd., which in the years that followed concentrated on the production of engines for the motor-car industry. With the changing policy of the motor-car industry, which led to motor-car manufacturers producing their own engines, Mr. Pelham Lee's company took up the manufacture of diesel engines and trailer fire pumps, and petrol-driven electric generating sets. Until a recent spell of ill-health, Mr. Pelham Lee continued to take an active part in the affairs of his company and made many business visits to overseas countries. He became an associate member of the Institution of Mechanical Engineers in 1905 and was elected to full membership in 1924.

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

MELTING POINT OF CHROMIUM

SIR,—In your issue of August 1, 1952, is an article on the melting point of chromium, in which reference is made to a new determination by Bloom *et al*[1] and to two earlier determinations[2, 3]. There is, however, no specific mention of the recently published results of Carlile, Christian and Hume-Rothery,[4] and of Greenaway, Johnstone and McQuillan[5] of these Laboratories. These investigators give figures of 1860 deg and 1845 deg. Cent. respectively. The agreement is thus quite reasonably good, especially since the results were obtained by entirely different methods (optical and thermocouple pyrometry respectively). The purity of the metal used in both cases was of a high standard, and allowance was made for the presence of impurities in arriving at the final figures. In particular, the total impurities in the chromium used by Greenaway *et al* was of the order of 0·1 per cent. This compares favourably with the figure of 0·35 per cent in the metal used by Bloom *et al* (1903 deg. Cent.); incidentally, this figure takes no account of possible additional impurity being introduced during the melting point determinations. The earlier work[2] of Smithells and Williams (1920 deg. Cent.) was done on electrolytic and thermit chromium of unspecified purity, but the total of impurities in their material is not likely to have been less than 0·5 to 1 per cent. Also the experimental method of these investigators could not be expected to give more than an approximate result.

In view of these facts, it is believed that no present-day appraisal of the melting point of chromium can afford to ignore the determinations made by Greenaway and Carlile and their respective collaborators.

F. W. DAVID
Acting Chief Superintendent,
Aeronautical Research Laboratories
Melbourne, January 12th.

SIMPLICITY IN GEARS

SIR,—A point in Dr. Merritt's letter calls for comment. It is not quite true to say of the paper he mentions that in it I "forecast the appearance of revised British gear standards." The paper referred to certain proposals that were being discussed by certain committees of the B.S.I.; it did not assert, or imply, that they had been accepted. As Dr. Merritt suggests, it would be wrong, even if it were possible, to anticipate official publication of a standard.

General discussion of a future British standard may or may not be new, but every draft standard is circulated to industry for comment, and the committee concerned with the gearing standards under discussion specifically agreed that the new proposals should be given the widest publicity in the hope of eliciting comment from everyone who might be interested.

It is not intended to set out any British Standard system of gear design, but on the other hand to endeavour to make clear to gear designers that the involute system offers much more latitude than many of them seem to realise and to show how that latitude may be used by design procedure much simpler than any that can be deduced from present British Standards. Above all, it is hoped to produce such specifications that the committee may safely offer to advise on any gearing job that appears to be beyond the possibilities of British Standard cutters.

W. A. TUPLIN

Sheffield, 1, January 23rd.

[1] D. S. Bloom, J. W. Putman and N. J. Grant, *Journal Metals*, June, 1952, Vol. 4, page 626.
[2] C. J. Smithells and S. V. Williams, *Nature*, 1929, Vol. 124, page 617.
[3] E. Friemann and F. Sauerwald, *Z. Anorg. Chem.*, 1931, Vol. 203, page 64.
[4] S. J. Carlile, J. W. Christian and W. Hume-Rothery, *Journal Inst. Metals*, 1949, Vol. 76, page 169.
[5] H. T. Greenaway, S. T. M. Johnstone and M. K. McQuillan, *ibid.*, 1951, Vol. 80, page 109.

ODE TO A TRANSPOSITION

John Brown had a body
embalmed in a song,
And also a name it is
hard to spell wrong.
But when printers, their readers
and editors, too,
Take a hand in the game,
Just between me and you,
It really surprises me what
they can do.

"DOGGEREL"

January 23rd.

[See page 134, THE ENGINEER, January 23rd; our apologies are due to "Jonh" Brown and Co., Ltd. !—ED THE E.]

National Research Development Corporation Report

THE report and statement of accounts of the National Research Development Corporation for the year ended June 30, 1952, has now been published. The report shows that the Corporation held the rights in some 1736 inventions, of which 960 had been applied for or granted in this country, and of these no less than 844 were from Government Departments or research councils and 87 from universities.

A number of examples are included in the report of projects selected for development by the Corporation. Electronic digital computors formed the subject of 99 inventions assigned to the Corporation. The confidence the Corporation has in the future importance of these machines is shown by the fact that it had placed a contract for the supply of four more similar to the one installed according to the designs of Professor Williams at the Manchester University. The report states that a further contract was being placed for a prototype machine of a very much smaller size based upon the development of special techniques, which, it was hoped, would reduce costs and increase reliability. Grants were also made to the Imperial College of Science and Technology for experimental work in the field of hydrocarbon synthesis. In connection with the work on diffraction gratings carried out by Sir Thomas Merton, further fundamental work had been carried out at the National Physical Laboratory, and a block of patents and patent applications had been assigned to the Corporation. Of particular interest is the statement that the Corporation is sponsoring a project put forward by Sir Harry Ricardo for the development of a light steam engine.

During the year under review no new financial sponsorship was provided for the development of inventions by private individuals unconnected with industry, although some submissions were being studied.

BOOKS RECEIVED

Practical Motorist's Encyclopedia. Eighth Edition Revised. By F. J. Camm. London: George Newnes, Ltd., Tower House, Southampton Street, Strand, W.C.2. Price 17s. 6d.

Worked Examples in Illuminating Engineering. By R. W. Ames and J. B. Harris. London: Macdonald and Co. (Publishers), Ltd., 16, Maddox Street, W.1. Price 21s.

Sound Recording and Reproduction. By J. W. Godfrey and S. W. Amos. London: Iliffe and Sons, Ltd., Books Department, Dorset House, Stamford Street, S.E.1. Price 30s.

Definitions and Formulae for Students. Second Edition. By L. S. Powell. London: Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, W.C.2. Price 1s. 6d.

Design of Precision Grinding Machines

THE INSTITUTION OF MECHANICAL ENGINEERS

A PAPER entitled "Design of Precision Grinding Machines" was presented at a meeting of the Institution of Mechanical Engineers by Mr. G. H. Asbridge* on Friday last, January 23rd. A summary of the paper and the discussion is given below.

Summary

In this paper are put forward the basic principles under which all grinding machines, irrespective of size or type, must be constructed. The chief problems facing the designer of precision grinding machines are discussed, together with the essential elements and physical components. The choice of solutions which seem to offer the most promising future developments is suggested. The factors affecting the design of grinding machines—cost, ease of maintenance and the influence of the user—and the essential elements—rigidity, accuracy, and constancy, are discussed. Mechanical and hydraulic traverse mechanisms are compared and a brief description is given of a typical hydraulic system. Although mechanical methods of traverse have been giving way to hydraulic systems, the author considers that with the improved electrical control gear available there may be a reversion to mechanical traverse mechanisms on account of their simplicity and reliability.

The influences of the wheel head and wheel head spindles are discussed. The two lines of approach that wheel head design and wheel head speeds will follow during the next few years are suggested. Work head and work head drive arrangements are described, followed by the main features of universal machines and machines arranged for automatic operation.

Finally, methods and mechanisms are described for obtaining concave and convex camber with roll grinding machines.

Discussion

Mr. C. A. Sparkes said that the author's policy of clearly stating that design must always be a compromise, together with the numerous practical examples of the alternatives available to the designer, was a sound contribution to good relationships between maker and customer. The idea of reviewing the difficulties of design gave the user the opportunity of seeing that all possible aspects of the problem were being considered.

When the author stressed the need for rigidity and minimum vibration, he found it difficult to understand why the main driving motor appeared to be virtually hanging on to the headstock, in the case of one of the machines shown.

He fully agreed with the author on the quality of finish on components that could be obtained from a machine with plain bearings compared with one fitted with a ball and roller arrangement, but he could not believe that the explanation was quite so simple as suggested. Here was undoubtedly a question for the research organisations to carry out a full investigation into the behaviour of bearings when supporting spindles under operating conditions.

There was no doubt that precision grinding machines had reached a very high standard, yet the question of wheel balance, setting steadies when machining long slender spindles with keyways, and many other problems, still demanded considerable skill on the part of the operator.

Mr. N. Stubbs (London) said that the author's reference to a reversion to electro-mechanical traverse mechanism was particularly interesting. There had been developments on these lines in various kinds of machine tools during recent years, sometimes associated with fully automatic operating features. They had been criticised in some quarters as being over-elaborate, but a number of successful applications had been made in practice. As this means of providing a closely controlled automatic motion on machine tools was developed, with the improvement and increasing reliability of electrical and electronic equipment and probably with standard replacement units, it seemed inevitable that there would be further development on these lines.

Mr. C. L. David (Keighley) suggested that greater stress would be justified when mentioning rigidity of the machine to consider freedom from vibration. Rigidity was not only necessary to maintain alignments, but also to avoid vibrations from being transmitted to the work. Vibrations could come from an external source or from the machine elements themselves. The best way to suppress any vibrations from the machine elements was obviously not to allow any to develop. The balance of rotating parts, particularly of motors, avoiding both mechanical and electrical vibrations of the motors, resilient mounting of pump units, accurate manufacture of hydraulic pump elements and relief valves, use of the highest class ball or roller bearings, or, in many cases of plain bearings on the rotating elements, became of over-riding importance.

He wholeheartedly agreed with the author that the general acceptance of hydraulic drives for grinding machines did not mean that mechanical means for table drives in particular had outlived their usefulness, especially in view of the fact that mechanical means, being more direct and inherently stiffer, avoided some of the difficulties encountered at slow traverse speeds due to the flexibility of the hydraulic drive.

On the other hand, he was still rather sceptical of the reliability of electrical control gear. There was no doubt at all that electrical control gear was very versatile and permitted the simple combination of many interdependent controls. But, so far, his experience had been that electrical control elements were not as reliable as their hydraulic counterparts.

He queried the author's statement that wheel speeds for all external operations would be lower than in the past to obtain free cutting properties and an economic wheel life. It struck him that the author was generalising from an experience with roll grinders which was not applicable to most production grinding jobs.

Wheel structure, suitable cutting coolant and facilities for dressing, might well prove to give increased production at higher rather than at lower wheel speeds.

He queried the explanation of the superiority of plain bearings on work heads. The author said that they controlled the spindle over a longer length and prevented a tendency for it to bend. Was not a more likely explanation to be found in the fact that the plain bearings consisted of fewer parts than rolling bearings, which normally, at least, consisted of two rings, an outer and an inner, about nine to twelve balls, and a cage? The more parts there were, the greater was the chance of inaccuracies, and the very high contact pressure between the ball and its race was likely to squeeze out the oil and lead to a harsh metal-to-metal contact. This harsh contact was less likely in the case of plain bearings.

It was perhaps not fair to discuss the one hydraulic circuit that the author had illustrated. On the other hand, he would most readily agree with the author's insistence on the simplicity of the hydraulic circuit. But why had the author selected a pilot control system? A pilot controlled reverse valve had many advantages—fingertip control, a very short reversal stroke, and one could assure reversal even at the slowest table speeds without very fine matching of ports and load and fire mechanisms. On the other hand, a pilot-controlled reverse valve had the drawback that one could not hold the table against the reverse lever at the point of reversal when grinding against shoulders in order to avoid taper or barrelling. To overcome that difficulty, it then became necessary to introduce dwell valves, possibly with separate control for left-hand and right-hand end, dwell selector valves, and thereby complicate the system again.

He agreed with the author about the provision of a double swivel on the universal machine in that the advantages of a double swivel were very small compared with its drawbacks. Most of the advantages could be obtained without it by the use of a suitable taper dressing device. Obviously a double swivel meant an additional pair of slides under the wheel head, with an attendant loss of rigidity and the necessity of reduction of wheel size, which reduced the productivity of the machine. He therefore strongly suggested that users should be discouraged from requesting double swivels.

He did not wish to dwell too long on the advantages of automatic sizing. He wanted only to correct what appeared to him to be a misunderstanding of the normal arrangement of sizing devices. The sizing devices which contacted the work, and which his firm had used for a long time, were normally synchronised with the positive stop on the wheel infeed. They did, therefore, always work with a dwell period; in fact, one might put it that they controlled the dwell period. The latest devices allowed for two stages, the first stage stopping the feed and the second stage controlling the spark out and retracting the wheel head when reaching the size.

Mr. H. S. Hull asked whether it was likely that the safety regulations with regard to grinding wheel guards were to be stiffened. He thought that something more should be done by the makers in this respect, since although the regulations were fairly stiff, they were still lacking in certain aspects.

He was glad that there was now a movement back to the mechanical traverse. During the war he had had a great deal of trouble with hydraulic mechanisms, and he would be delighted to see the mechanical traverse come back, with some improvements.

Mr. Low, referring to electro-mechanical drives, felt that the paper would be helped if there could be some contribution from the people who had served on the Servo-Control Panels during the war. He understood that two teams had been working—one on electrical, one on hydraulic—both of which had been equally successful. Speaking from memory, he thought that the figure was that one could slew two 6in guns to 180 deg. within twenty seconds and bring them up within five seconds of arc. He thought that any remarks which those people might be able to make in the written discussion would be of considerable interest.

Mr. G. H. Asbridge then replied to the discussion. Mr. Sparkes had asked why put the main motor on the wheel head when one was seeking rigidity; why put it on the wheel head when it was running round and in close proximity to the wheel; why not put it on the floor? To reply to that point, in his firm they obtained, in the first place,

* Chief designer, Churchill Machine Tool Company, Ltd.

motors which were balanced to a very high degree of balancing to a specification which was agreed between themselves as manufacturers and the motor manufacturers. They checked all the motors that came to them to ensure that they were within the specification laid down, and the motor manufacturer used the same method of checking. They held to very close limits of balance and on the whole he thought it would be found that the lesser evil was to put the motor on the wheel head.

He firmly believed that in the case of a grinding machine, if one was on accurate work, the machine should never be stopped. It should be run day and night, week after week, until it was worn out. If one really wanted to get the best from the grinding machine bearing, the wheel spindle should never stop and should keep on going until the machine was finally finished with. Of course, that was impossible to achieve in practice, but it was a fact that many manufacturers on very accurate work, if they were not working a night shift, did arrange for the machines to be started up at four or five o'clock in the morning so that by the time the workmen came in at 7.30 or eight o'clock the machines would be at their operating temperature. That had been found to be the only true way of getting at the right temperature.

Several contributors had referred to the movement away from hydraulics to mechanical traverses. In that matter, he had referred specifically to the case where a machine had a hydraulic traverse and a pump and all that went with it purely for moving a table backwards along the body. He thought there was a very good case for hydraulics when one got auxiliary movement as in crankshaft grinding machines. This was a wonderful example of hydraulic control ; it was flexible, and it could be made to work in several directions at once, and it was extremely useful. But where he thought hydraulics were on the way out was when used purely and simply as a reciprocating motion for a table. That was an example of the waste of power which a hydraulic mechanism occasioned. He thought that hydraulic power was extremely wasteful, and where it could be got rid of in the future he thought it should be.

Mr. David had raised the question of low speeds of wheels. He quite agreed that the experience was based on roll grinders, but whether it was untrue for flat grinders, he did not know. What he had been trying to get at was that if wheel spindles and bearings became more and more rigid, the manufacturers would be forced to come to softer and softer wheels. They might quite easily—and this was a point that gave him quite a lot of thought—reach the point where the spindles would be so rigid that the grinding wheel people could not make wheels soft enough to grind with ; they would just fall away and have no life.

What he had really meant when referring to low wheel speeds was that to overcome that it would be necessary to go harder with the grades of wheel and lower the speed to soften the effect ; in other words, to help the wheel people out by using a harder grade of wheel and running slower.

He agreed that it would be a good thing if one of the research associations would find out why it was that a plain bearing was better than a ball bearing for applications such as wheel heads and work heads.

With regard to the universal grinding machines with a double swivel under the wheel head, he agreed that one did not want this very often, but when one did want it one wanted it very badly. The use of truing devices and putting angular faces on wheels was not very satisfactory as a means of getting a very good finish.

On the question of dwell for sizing gauges, Mr. David had said that what he did was to set the sizing gauge and the dead stock of the machine so that the two were synchronised. Of course, one must do that, but for how long would they be synchronised ? Theoretically, there had to be some advance on the wheel over the sizing gauge, otherwise it would never reach size. There had to be that little bit of advance so that the wheel was pushing the job that little bit so that the spring of the job could come down to size. Virtually, one did get the two synchronised. As soon as the wheel wore a little, then the wheel could not quite reach to that point, and so one went on for a long time before the sizing gauge said " Right." One did in fact get a dwell, but one also got a very variable time cycle, which was what people did not like ; they wanted a controlled cycle. Mr. David said that it could be done in two or three stages, but why not have dwell and have done with it ?

Mr. Cooper and Mr. Hull had been very much interested in the safety of grinding wheels. The Home Office safety regulations were very much out of date and were at the moment being rewritten. He gathered that the new edition would be published inside twelve months. Obviously he could not anticipate what those regulations would say, but he thought that there would be considerable changes.

He had been rather surprised to hear that there was apparently a great deal of wheel bursting. He had not himself had a wheel burst in the last six years since he had been back with the Churchill Machine Tool Company.

There were, of course, many factors which contributed to the bursting of a grinding wheel. It could be due to a faulty wheel, but that was very unlikely, especially if one ringed the wheel. If one did so, one could be very sure that the wheel was safe. What happened when it was mounted was another matter, and much depended on the person responsible for seeing that the wheels were mounted properly.

On the subject of servo controls applied to machine tools, there were machine tools supplied with servo controls, e.g. milling machines ; but at the moment there were no grinding machines with them on, mainly, he thought, because it was possible to do what one wanted without them. Moreover, it was one thing to have a servo control on a milling machine working to 0·002in or 0·003in, and it was quite another thing to have one on a grinding machine working to within 0·00025in. Another thing to be remembered was that when it was a matter of moving big guns to very close limits, the taxpayers were paying for it ; when one put a servo control on the machine tool, one paid for it oneself ! One of the things that militated against servo controls was cost, plus the fact that any manufacturer who exported his machines had to keep them reasonably simple, otherwise if anything went wrong on the machines when they were at the other end of the world, there would be nobody there to put them right.

The Elizabeth River Crossing

(*By our American correspondent*)

With the opening to traffic on May 23rd last of the bridge and tunnel project crossing the Elizabeth River between Norfolk, Berkley and Portsmouth, Virginia, an important link has been added to the highway system along the east coast of the United States. The bridge part of the scheme is 2135ft long between abutments and comprises a double-leaf, rolling-lift bascule structure of conventional design. The tunnel part of the project, with which this article deals, is 3350ft long and was constructed by prefabricating and sinking seven 300ft tube sections into a trench dredged across the river bottom.

NORFOLK, Virginia, one of the great natural harbours on the east coast of the United States, lies on the estuary of the Elizabeth River. Here, the river forks so that the three shipping areas of Norfolk, Berkley and Portsmouth, with their valuable and sheltered dock space, are separated from each other by busy waterways. Before the last war the need for direct links across the river's branches had become obvious. In 1942, the General Assembly of the State of Virginia created the Elizabeth River Tunnel Commission for the purpose of planning and constructing a motorway tying together Portsmouth, Berkley and Norfolk. Its route is 1·8 miles long, extending from a plaza in Portsmouth, across the tip of Berkley, to a plaza in Norfolk. The Commission decided on a tunnel crossing for the southern branch because of the great use of this portion of the river by ocean-going vessels and because of the position of the U.S. Navy Yard upstream of the crossing. On the Berkley peninsula the tunnel emerges from the ground. The eastern branch of the river is crossed by a bridge, making the construction more economical than an all-tunnel route. Furthermore, the acquisition of land in the centre of Norfolk for a bridge approach and a plaza proved simpler and less costly than for a tunnel entrance.

The cost of the entire project has been approximately 23,000,000 dollars and was financed by an issue of 3½ per cent revenue bonds to be paid off by 1980. Tolls, which in the case of motorists amount to 15 cents per axle plus 5 cents per rider in addition to the driver, are being charged for the tunnel crossing and being collected at booths on the Berkley side. The City of Norfolk is paying the tunnel commission approximately 190,000 dollars a year to keep the bridge over the eastern branch of the river toll-free.

The construction of the crossing scheme commenced in February, 1950, when the Elizabeth River Tunnel Commission awarded a contract to the Merritt-Chapman and Scott Corporation, of New York City, and the Tidewater Construction Corporation, of Norfolk, on the basis of a joint tender of 16,263,642 dollars. Under the terms of the contract, the former firm undertook the construction of the 3350ft long, two-lane tunnel and a single ventilation building situated on the Portsmouth side, while the latter company built the 2135ft long, four-lane bridge as well as the roadway approaches and plazas. Similarly, the design and supervision of construction was undertaken jointly by two firms of consulting engineers, Parsons, Brinckerhoff, Hall and Macdonald, of New York City, being responsible for the tunnel, the ventilation building and the Portsmouth plaza, and the J. E. Greiner Company, of Baltimore, handling the bridge with its approaches and the Berkley and Norfolk plazas.

Tunnel Design

The trench method of tunnel construction was chosen over the shield-driven method for the sake of economy, preliminary estimates indicating that the design selected could be built at about half the cost of a similar tunnel driven with a shield. Of the 3350ft length of

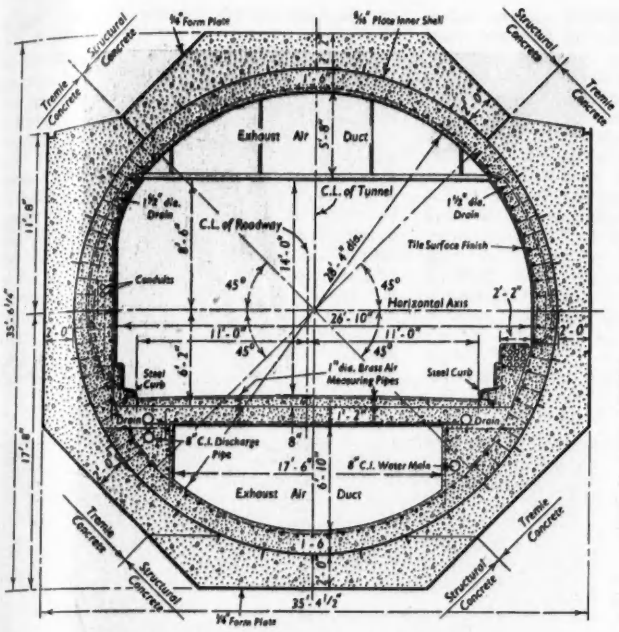


Fig. 1—Typical Cross Section of Tunnel Tube

the tunnel between portals, the subaqueous portion under the ship channel is 2100ft long, made up of seven sections of double-shelled steel casing, each 300ft in length. On either side of the underwater section, the remainder of the tunnel has the conventional box-type cross section built by cut-and-cover methods. From the portals, retaining walls flank the roadway over the rest of the distance of the respective plazas. A typical cross section of the tunnel tube is shown in Fig. 1 where the principal dimensions are given; diaphragms between the inner and outer shells are placed on 12ft centres along the length of the tubes. The seven sections of casing were fabricated for the tunnel contractor by the Bethlehem Steel Company at its Sparrows Point Shipyard, as shown in Fig. 5, and were launched in a manner similar to that employed with sea-going vessels. A temporary bow was fitted to each of the tubes to ease the pressure exerted on the forward bulkhead during launching. Once afloat, each section was taken into tow by tugs and brought to the tunnel site (Fig. 6).

As the tubes were being fabricated, concrete was placed in the keel of each section before it was launched from the shipways, the amount varying slightly according to the flotation required. This added weight of approximately 900 tons also served as ballast during the 180-mile tow down the Chesapeake Bay to the "shape-up" docks on the Berkley side of the river. Here the preliminary work was completed before the tubes were sunk, one by one, into prepared positions in the trench.

Concrete for the interior of the tubes was mixed on a floating plant and placed by pump. This work included completing the inner concrete ring, which is 18in thick, and pouring the haunches and the 14in roadway slab. The pouring of the kerbs, the service walkway on one side, and the roadway paving were left until the tunnel had been opened between its portals. Structural interior concrete was placed in the shell before sinking, leaving only the side pockets of the outer shell partially empty.

The finished inside diameter of 28ft 4in of the tube provides a roadway with a 22ft horizontal clearance between kerbs and a minimum vertical clearance of 14ft to the hung ceiling. The inner concrete ring is lined with glazed ceramic tile. Ventilation is provided by electrically operated fans centrally controlled from the ventilation building at the Portsmouth portal. Air is drawn in through the portals, and is exhausted through vents leading to ducts beneath the roadway and above the ceiling slab. Since the tunnel is comparatively short, this one-way system of ventilation was considered to be satisfactory.

Trench Work

Trench work for the tunnel was performed under a sub-contract by the Atlantic Contracting Corporation, of Norfolk, which used its bucket dredger "Atlantic." The sub-contract involved approximately 925,000 cubic yards of excavation for the trench; preparing the trench for the tubes by laying a 2ft sand foundation course on the bottom, and finally backfilling over the tunnel with a minimum cover of 5ft of sand. The main channel of the river is about 450ft wide with a depth of 45ft, and a proposed future depth of 50ft. This latter depth had to be maintained between the pierhead lines after the tunnel was laid, so that a cut almost 50ft deep had to be made in the river bed to contain the tubes. The depth of water decreases from the pierhead lines up to the shore, and at the deepest part of the tunnel the excavation went down to a −97·5ft mean low-water depth. The material which had to be dredged consisted of silt, coarse and fine sand, shells and clay. In the soft digging a 7½ cubic yard clamshell bucket was used; in the harder strata this was exchanged for a 6 cubic yard clamshell bucket.

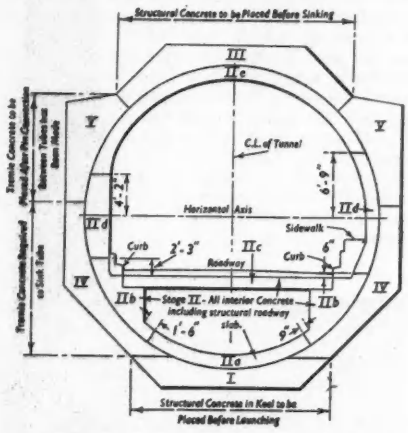


Fig. 4—Diagram Indicating Sequence of Concrete Placing

The "Atlantic" began dredging operations on the inshore side of the channel, working toward Berkley. As it reached shallow water, the dredger dug its own flotation. At the beginning of the work, the dredged material was loaded into a single steel-hull, bottom-dump scow having a 1000 cubic yard capacity, but as the work progressed three scows were used for loading and two tugs for towing, thus allowing one scow always to be at the dredger. Material was towed out into the Hampton Roads off Old Point, where a deep hole had been marked by the U.S. Army Corps of Engineers for use as a dumping area. The one-way haul involved a distance of about 12 miles. Dredging was carried on twenty-four hours a day, six days a week, with Sunday set aside for maintenance and repair work.

Concreting

Upon arriving at the tunnel site, the tube sections were moored to a "shape-up" dock where all work preparatory to sinking was performed. The main operation taking place at this stage was concrete emplacement—both inside the tubes and between their inner and outer shells. This work took six weeks for each tube. A number of tubes was handled simultaneously at the dock, with concreting operations following consecutively from tube to tube.

The sequence of placing the concrete in the

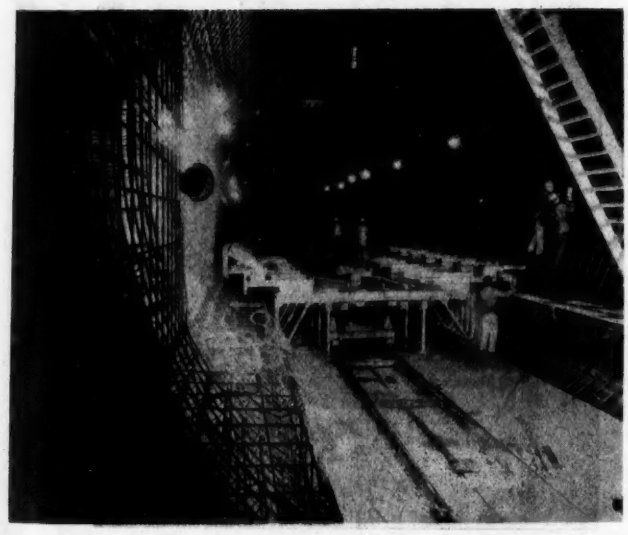


Fig. 2—Mould Bogie and Mould for Pouring Lower Haunches

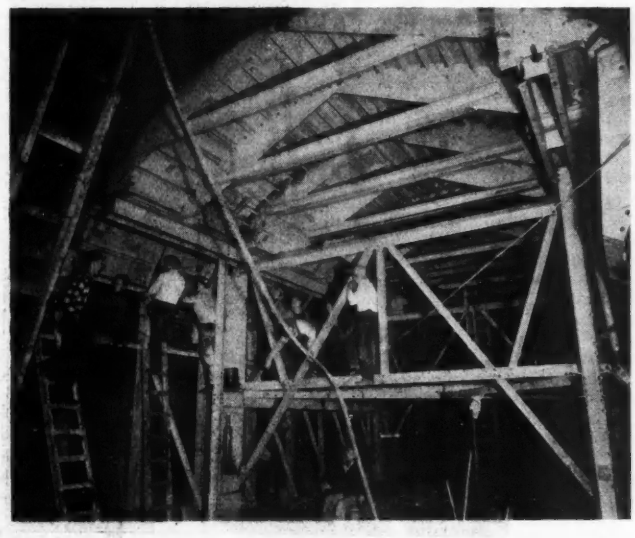


Fig. 3—Assembly of Moulds Preparatory to Arch Pour

THE ELIZABETH RIVER TUNNEL

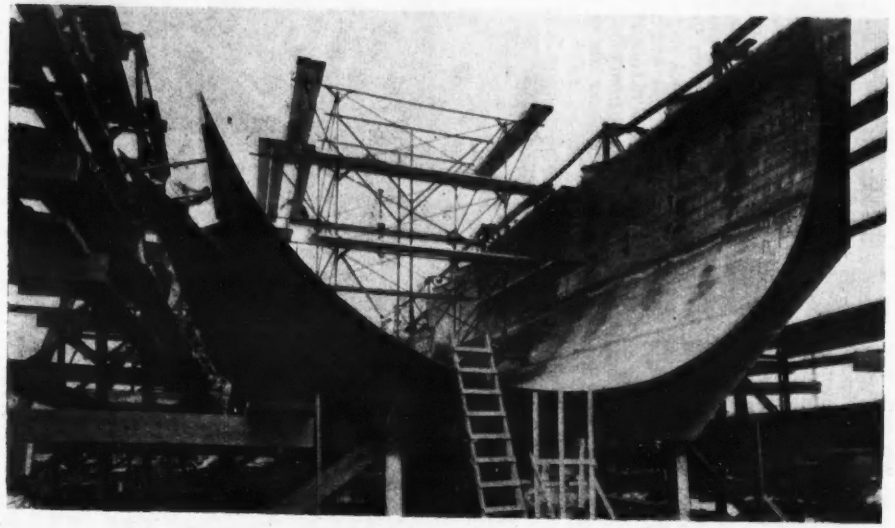


Fig. 5—Fabrication of Tube Section

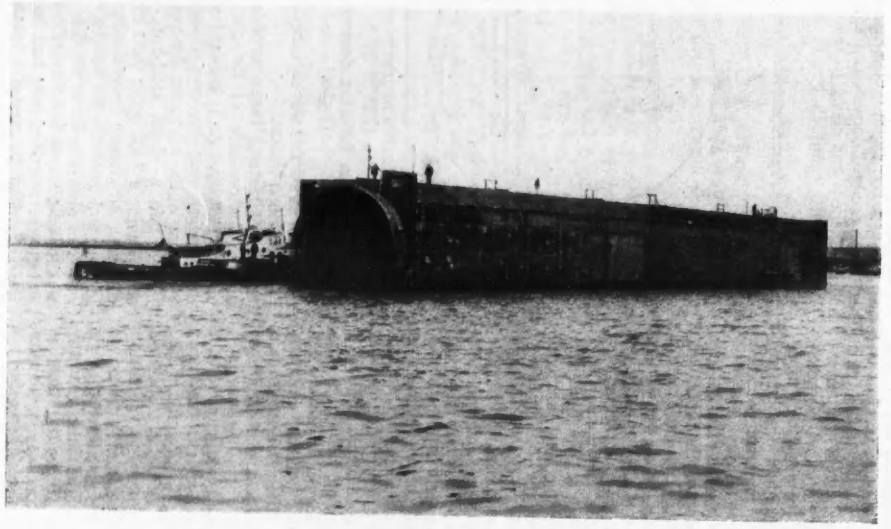


Fig. 6—Towing of Tube Section

Fig. 7—Open-cut Work at Berkley Portal of Tunnel

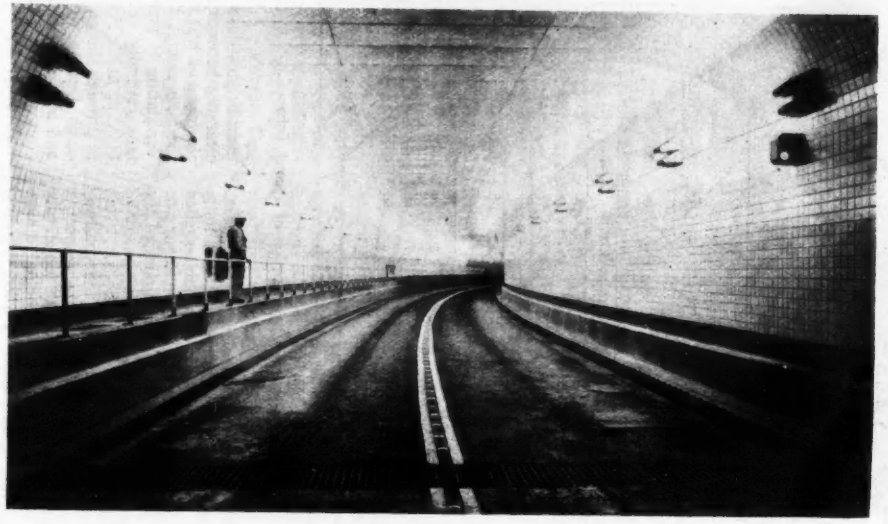


Fig. 8—Completed Tunnel Interior

tunnel tubes is shown diagrammatically in Fig. 4. Sectionally, the tube interior was poured at the shape-up dock in the following five consecutive stages :—The invert, the lower haunches, the roadway slab, the side walls and the arch. Generally, one stage was completed throughout the length of one tube before a subsequent stage was commenced. To maintain the 300ft long tubes in longitudinal balance, it was necessary to handle each stage in two steps involving a length of 150ft each. The first step comprised two 75ft pours centred at the quarter points of the tube ; the second step required the pouring of the central 75ft length of the tube as well as the two 37ft 6in ends. Concrete was mixed in a floating plant which was moored to an adjacent wharf. It was fed to the deck of the tube sections by pump and then dropped by trunks inserted through hatches in the tube shells. All interior concrete, with the exception of the invert, was placed with the aid of four 37ft 6in long steel moulds which were moved along the tube to their desired positions on a bogie. As the top hatch of each tube provided an opening of only 3ft by 5ft the mould and bogie structures had to be dismantled completely for movement into or out of the tubes.

Fig. 9 shows the internal appearance of the tubes upon arrival at the shape-up dock, with preparations being made for placing the invert. The invert slab is 18in thick and extends some 7ft on either side of the vertical centre line of the tube. It was placed in one continuous pour from end to end of each tube, requiring about eight hours. A 5ft gauge rail track was laid for the mould bogie on top of the completed invert slab, and Fig. 2 shows the moulds in position for pouring the lower haunches. The haunches extend from the edges of the invert slab and from the sides of the under-floor exhaust air duct, and they comprise a series of ledges designed to support the roadway slab, the kerbs and the sidewalk. The emplacement of the two 150ft lengths of haunches was generally completed in four hours each. Upon completion of the haunches in each tube the haunch moulds were removed from the bogie and the roadway slab moulds assembled on the structure instead. The roadway slab is 22ft wide and 14in thick, and was given an additional 6in of paving when the tunnel was opened between portals. To remove the moulds and the bogie frame from beneath the roadway, they had to be dismantled within the air duct exhaust and hoisted through a hole left open in the slab for that purpose. This opening was then closed with concrete placed inside wooden shuttering.

The difference in shape and thickness of the right and left side walls is indicated in Fig. 1. While the one generally follows the shell plate curve, making an 18in thick concrete lining, the other is vertical and is generally thicker, to encase certain conduits. An 18ft gauge rail track was laid on top of the roadway slab to carry the bogie structure which was used to support both the side wall moulds and the arch moulds. Fig. 3 shows the latter being mounted on the bogie structure preparatory to the arch pour. As the tunnel walls were eventually to be faced with glazed ceramic tile, it was considered desirable to obtain an improved bond surface for the tile-cementing mortar and, hence, lines of $\frac{1}{16}$in diameter wires, 4in apart, were permanently welded horizontally to the face of the mould panels. When the moulds were stripped, these wires not only left their own groove in the concrete, but spalled off some concrete, with the object of giving a good bond. Concrete was poured simultaneously in both walls of the tube. It was pumped through the tube hatch into a hopper mounted on a tower from which a chute led to each wall mould. The steel-framed tower was on wheels, and was pulled along the floor slab from hatch to hatch as required.

Placing of the arch concrete completed the work at the dock. With the exception of the edge where it meets the thickened side wall, the arch follows the tube radius and is 18in thick. All arch concrete was poured directly into the moulds through the tube hatches. On the second arch pour in each tube, concrete was omitted at the exit hatch and poured against suspended wooden shuttering after the steel moulds and the bogie had been dismantled and taken out of the tube. Finally, the tube shell was made continuous by welding plates over the former hatch openings. The appearance of the tube interior at this stage is illustrated in Fig. 10. Upon the completion of the internal lining concrete was poured around the outside of each tube, within the double shell, to lower its centre of gravity and to increase its stability. When ready for sinking, the freeboard of each tube was about 1ft and its displacement some 9100 tons.

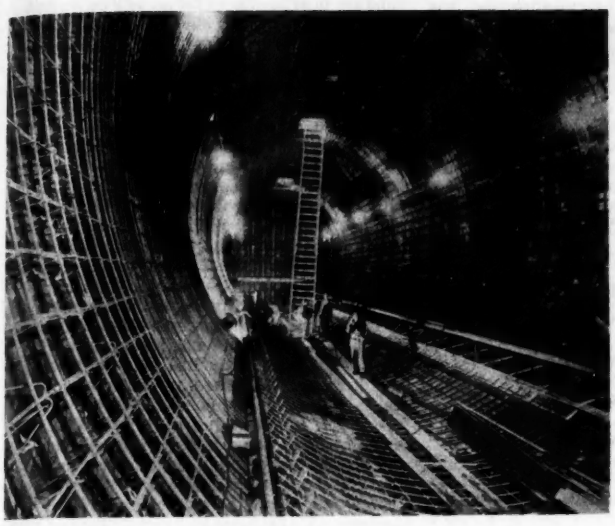


Fig. 9—Interior of Tube Section on Arrival at Shape-up Dock

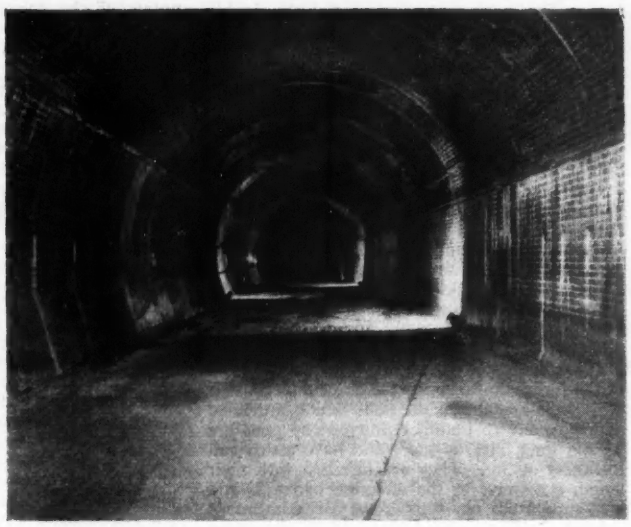


Fig. 10—Tube Section After Completion of Interior Concrete Lining

Sinking the Tube Sections

One at a time each completed tube section was towed over its ultimate position in the trench and was supported at each end by floating derrick cranes. Concrete was then poured from a floating mixing plant into the side pockets between the inner and outer shells of the tube by the tremie method until the tube was heavy enough to sink of its own weight. At this point, the supporting crane slings were gradually lowered and the tube was allowed to sink gently into its final position. Using instruments on shore sighting on tall temporary masts mounted at each end of the tube, it was possible to check the alignment and grade of each tube during the entire sinking.

The tube sections were fabricated with 1in thick semi-cylindrical hood plates extending 18in beyond each end. These plates alternated, top and bottom, so that when adjacent tubes were butted together, the cylinder halves met to form a ring that covered the joint between the shell plate. Also attached to one end of each tube were five heavy-duty ratchets. After each tube was lowered into place, divers descended to hook the ratchets over matching lugs on the next tube and tighten them to pull the tubes together. Then they inserted 5in diameter forged steel pins into other pairs of lugs at the abutting edges of the top and bottom hood plates, at mid-height of the tubes, to complete the first-stage coupling. Once the tube was joined to the adjacent one, six concrete blocks, having a submerged weight of 18 tons, were placed on top as temporary ballast to prevent any movement from taking place should the specific gravity of the water change while the tremie concrete envelope was completed.

The joints between adjacent tubes were poured after the next section had been placed. For this purpose, a length of sheet piling had been fastened to each vertical side of the square dam plates that formed the ends of the tubes. With the tubes sunk, divers threaded another pile into each of these knuckles and then placed a vertical semi-cylindrical closure shell into the piles of adjoining tubes. The shells, piles and dam plates thus acted as a mould into which concrete was poured by tremie to encase the joint completely. After the joint was poured, 10ft 6in of sand backfill was placed in the trench around the tubes. Ordinary backfill was then dumped on top of the sand until the tubes were covered with a minimum layer of 5ft of material.

The seven tubes were lettered A to G, from the Portsmouth to the Berkley side of the river. Tube G, abutting the Berkley shore, was sunk first in March, 1951. Tubes F and E were sunk in April, D and C in June, and A and B in January, 1952. Following the sinking of tube C, tube A was sunk and was drawn up close to the Portsmouth shore within a strongly reinforced wet trench about 50ft wide and ranging in depth from −65ft to −95ft, mean low water. Landward from the bulkhead at the end of the wet trench was a dry trench which contained the cut-and-cover section of the tunnel on land. The sides of the wet trench had been sheeted by long steel master and intermediate piles, and had been braced with other steel sections stretched across and beneath the surface of the water. Tube B was sunk into position last, and was fitted in between tubes A and C in one of the most difficult operations of the entire scheme. The sinking of tubes A and B was necessarily almost a continuous operation.

In November, 1951, the end or east bulkhead of tube G was removed with oxy-acetylene

torches, thus giving access from the Berkley shore to the initial 300ft tunnel section. Ten days later the joint G–F was dewatered, and the west bulkhead in G was removed. The bulkhead plates were burned out along the line of the inside concrete ring; beams supporting the bulkheads were removed similarly. Subsequently, the adjacent east bulkhead in F was burned out, and that tube was entered. Joint F–E was dewatered, and the west bulkhead in F was removed in December. Shortly afterwards, the east bulkhead of E was burned out. Before working on the E–D bulkhead, the contractor went back to the first two joints—G–F and F–E—and completed the final joint welding and grouting. The dewatering and removal of the bulkheads in the tunnel then proceeded toward the Portsmouth shore.

On the Portsmouth side, the contractor also built a steel-sheet-piled bulkhead and anchorage cell to protect the property of the Seaboard Air Line. The contractor underpinned the double tracks of the line and constructed a railway bridge so that train service was continued without interruption during construction. On the Berkley side, the 625ft approach section was carried out by the open-cut method (Fig. 7). The main feature there was the construction of a railway trestle and bridge for the track of the Norfolk Southern Railway crossing the project.

Once the "holing through" of the tunnel had been completed, the tube interior was finished, including the tiling of the walls, the installation of a hung metal ceiling, the final paving of the roadway, the building of a patrol and inspection walkway along one side of the tunnel, and the installation of strip lighting fixtures. Fig. 8 shows the appearance of the completed tunnel interior. The use of a hung metal ceiling is a particularly interesting aspect of the tunnel construction. The ceiling consists of porcelain-enamel steel pans which are filled with concrete to obtain rigidity. The pans are 7ft 6in long, 2ft 7in wide, and have an overall thickness of 3in. They are installed with their length transverse to the direction of traffic and are supported on four rows of continuous stringers. The stringers are hung from the concrete tunnel lining by anchored rods. The joints between the individual pans are sealed with a ¾in diameter hollow plastic tube filler strip and with caulking compound.

This design of tunnel ceiling construction was developed by Parsons, Brinckerhoff, Hall and Macdonald, the consulting engineers on the tunnel, in collaboration with Seaporcel Metals, Incorporated, of Long Island City, New York, and it is claimed to have several advantages over the conventional hung concrete slab and tile unit construction. Its total overall thickness of only 3in offers the opportunity, it is said, for a given tunnel section, to gain either about 6in more vertical clearance, or 20 per cent additional cross-sectional area in the upper air duct. The comparatively large size of the porcelain units, it is claimed, together with the method of mechanical fastening to the supporting stringers rather than adhesive attachment to a slab, as in the case of tiles, reduces the field installation work to a minimum and offers a simple and fast method of replacement. It is also pointed out that experience in recent tunnel fires in the New York area has shown that the concrete lining expands due to excessive heat, detaching the small tile units and projecting them into the traffic area at dangerous velocities; the special porcelain coating is highly resistant to rapid changes in temperature, remaining unharmed even when subjected to 1600 deg. Fah., and the mechanically supported units eliminate the missile hazard entirely. It is anticipated that this ceiling will be easier to wash and clean due to its extremely hard and smooth surface and the great reduction in joint area as compared with the more conventional small-sized tile construction. Adjustment of the ceiling height can be accomplished after installation by U-bolts that support the stringers, allowing a final check and correction, if necessary, after the roadway surfacing has been placed. Many observers have remarked that this ceiling, with only two parallel joints along the roadway, presents a more pleasing appearance than the small-sized pattern established by tile units.

Reconstruction of Skipton Engine Sheds

WHEN the renewal of the old timber-built engine sheds at the Skipton motive power depot on the London Midland Region became a matter of particular urgency, a year or so ago, it was decided, in view of the steel situation, to adopt a design using old rails which had been developed on the Southern Region of British Railways. The design evolved consists of Warren roof trusses constructed from serviceable bull-head rails having bolted connections and spanning between new brick walls. The side walls are provided with ample glazing, the coverings being of continuous glazing in timber bars on one slope alternating with asbestos cement corrugated sheets, supported by bull-head rail purlins secured to the diagonal truss members.

Ventilation in the buildings is provided by a continuous covered opening at the upper node points of the trusses. This arrangement has proved to be most satisfactory and smoke is quickly dispersed without the use of smoke troughs.

The trusses were manufactured by the regional mechanical and electrical engineer at Horwich works and assembled on site by direct labour. We are informed that plans for this work were put in hand in January, 1952, and the twin sheds, 180ft and 120ft long respectively by 46ft wide, were completely demolished and rebuilt by the middle of September last.

Asian Coal and Iron Ore Resources

A REPORT which has been prepared by the United Nations Economic Commission surveys the coal and iron resources of Asia and the Far East. This report says that considerable efforts have been made in the last few years by Asian countries to develop coal and iron resources, indigenous industries have been started, production increased, the quality of low-grade deposits improved, and the conservation of higher-grade deposits facilitated.

It is pointed out that despite the importance of coal and iron ore for the sound planning of industrial development, the Asian region is inadequately explored with regard to coal and iron resources. So long as these wide gaps persist in the knowledge of existing mineral resources economic development plans cannot be based upon firm realities.

The report estimates that the known coal reserves of Asia and the Far East total some 557,000 million tons, of which some 445,000 million tons are in China, 68,000 million tons in India, and 20,000 million tons each in Indo-China and Japan. The known iron ore reserves of the region are estimated to total almost 11,000 million tons, of which 5087 million tons are in India, 4168 million tons in China, 1019 million tons in the Philippines, and 889 million tons in Indonesia.

Books of Reference

Directory of Shipowners, Shipbuilders and Marine Engineers, 1953. London: Tothill Press, Ltd., 33, Tothill Street, Westminster, S.W.1. Price 40s.—The *Directory of Shipowners, Shipbuilders and Marine Engineers*, 1953, which has just been published, is the fifty-first edition of this work; it has been heavily revised and much new material added. The two main sections contain concise information relating to the principal shipowning, shipbuilding and marine engineering companies of the world. Ship particulars are given of individual units which make up the fleets of the various shipping lines and the number of berths and building capacity of the shipyards is recorded, together with the maximum horsepower output of machinery. In both sections the names of directors and technical personnel are included. Consulting naval architects, marine engineers and surveyors are listed, and also the various trade organisations and technical societies connected with the industry. Classification societies, together with a list of surveyors and outports are given, followed by details of the various Government departments. Five comprehensive indexes, which are included, give names of ships; names of shipowners, ship and engine builders, arranged alphabetically in order of countries and towns; telegraphic addresses; a general index, and a personal index to directors and officials of companies and of personnel, associations, &c.

"EUSEC" Conference on Engineering Education

AT the second Conference of the Representatives of the Engineering Societies of Western Europe and the United States of America (E.U.S.E.C.), which was held at The Hague in 1951, it was agreed that an exploratory conference should be held on the subject of the education and training of professional engineers.

At the invitation of the Institutions of Civil, of Mechanical and of Electrical Engineers, this conference was held in London from January 12 to 17, 1953. Delegates from Belgium, Denmark, France, Germany, Holland, Italy, Norway, Sweden, Switzerland, United Kingdom and the United States attended the conference and were chosen by the respective engineering societies to include representatives of the universities and industry in each of the countries. It unfortunately proved impossible for any delegates from Finland to attend.

Objects of the Conference.—The diversity of methods in the education and training of professional engineers in the different countries made it essential that, as a preliminary, efforts should be made to establish a better mutual understanding of those methods. The first five working sessions were devoted to an exchange of views of mutual problems, while at the sixth and final working session consideration was given to the future of the conference so that its work, so usefully begun, could be continued.

Working Sessions.—The first and fourth working sessions were held under the chairmanship of Mr. A. S. Quartermaine at the Institution of Civil Engineers, the second and fifth sessions were held under the chairmanship of Dr. S. Livingston Smith at the Institution of Mechanical Engineers, and the third and sixth sessions were held at the Institution of Electrical Engineers under the chairmanship of Mr. S. E. Goodall and Professor Willis Jackson respectively.

The first two working sessions were devoted to the presentation by each country in turn of a memorandum on the methods adopted by that country. To facilitate this part of the conference each country had prepared a memorandum on its education and training methods, which was sent to all delegates some time before the conference. At each of the subsequent working sessions specific topics were chosen for discussion.

Standards and Criteria of Entry.—Under this heading there was an exchange of opinion on the standards attained by prospective engineers at school leaving age. It was evident that there were three distinct conceptions of the necessary scholastic standard of young men leaving school. Certain countries, which included the United Kingdom and France, required a high standard of mathematics, whereas others did not insist on so high a mathematical standard and, indeed, one country, Switzerland, placed much greater emphasis on the need of a classical education. Other countries fell between these two extremes, but, in general, the various requirements for entry into the university in the different countries could be said to have no marked effect on recruitment. The age of entry into the university was almost invariably eighteen-plus years.

Basic Science and Technological Studies.—All countries were agreed that the function of the university was to give, at least in the early years of the university course, as wide as possible grounding in the basic sciences. In certain cases there was greater emphasis on specialisation in the later years, particularly where the university course lasted for up to five years, but all countries agreed that no attempt was made to produce a specialist of one narrow field of engineering science.

The definition of technological studies proved difficult, as a practical science like engineering must inevitably include in its study examples of practical application. It was evident that no country believed in so specialised a course as to produce technologists in a narrow field, but nearly all acquainted the student with technological developments through lectures given by experts drawn from industry who gave their services to the university on a part-time basis. Certain universities, particularly those on the Continent, had arrangements for their students

to go into industry during their vacations for the same purpose.

General Studies.—While there was general agreement of the necessity for the student engineer to enlarge his mind in subjects not connected with engineering so that he could take his rightful place among other professions, there was revealed a wide diversity of method. Some European universities included the humanities in their studies on a compulsory basis ; others found that the study of music, drama, history, biology and such subjects could be adequately covered by voluntary studies usually organised by the university, but sometimes by student organisations with university support. A compulsory study of economics, law and management was fairly general in all universities, though they were rarely included as credit subjects for the degree.

Practical Training.—One of the most useful aspects of the conference was the clarification of many misconceptions between the different countries on the subject of practical training. All countries were agreed that an engineer could not be regarded by his fellows as a professional engineer until he had had at least a short period in industry. In the United Kingdom this period lasted two years and took the form of organised practical training in industry in collaboration with the professional institutions. In other cases the experience was gained during a period of six to twelve months in industry while the student was under the control of the university. In one or two countries it was necessary for the student to obtain some practical training in industry before he entered the university. In other countries such a deliberate scheme of training was not practicable because of the size of that country's industry, or for geographical reasons. Nevertheless, it was evident that the initial years after leaving the university were in the nature of training and that no country wished to produce a ready-made engineering graduate capable of taking on a responsible position in industry.

Requirements for Conferment of Professional Status.—This problem resolved itself into a discussion as to the moment in the progress of his education and training when an engineer could be regarded as a fully qualified professional engineer. The position in the United Kingdom was unique in that the professional institutions granted this status by election of the young engineer to corporate membership, the conditions for which they alone decided, there being no legal requirements to practise as an engineer. In many countries—for example, the United States —while there was no legal requirement for the qualification of an engineer in a subordinate position, engineers who were to sign or approve engineering projects had to be registered by the law of the country. In some countries—for example, Italy and Switzerland—graduates of the engineering universities were regarded in law as fully qualified engineers, but it was evident that although this was the legal position the engineer would not be regarded by the profession as a fully qualified engineer at this stage of his career.

Exposition of the British System.—To facilitate a better mutual understanding the opportunity was taken during the conference of showing the delegates the British system of education and training in operation.

On the first day of the conference the delegates lunched at the Westminster Technical College, where it was explained to them that the College, in addition to courses in engineering, also gave courses in a wide variety of subjects, including hotel management. On the second day the delegates visited the City and Guilds College of London University where they were able to see the engineering laboratories of the College and were given an exposition of the British engineering educational system by Professor Willis Jackson before a dinner given by the Provost of the College. On the third day the delegates visited Brighton where they saw a typical municipal technical college, which includes a civil engineering course leading to a diploma of the College recognised by the Institution of Civil Engineers, in addition to courses in mechanical and electrical engineering leading to the Higher National Certificate. After a visit to the Royal Pavilion the delegates were entertained to dinner by the Mayor of Brighton.

On the fourth day the delegates spent the whole day at Rugby where they visited the works of the British Thomson-Houston Company and the English Electric Company. During these visits the delegates saw the kind of work upon which graduate apprentices in mechanical and electrical engineering were engaged during their practical training and had opportunities to talk to several of the apprentices. The delegates also visited the apprentice hostels of the two companies. The training schemes at these two works are closely integrated with the Rugby College of Technology and Art, which was visited in the evening. The delegates were entertained to lunch by the British Thomson-Houston Company and to cocktails by the English Electric Company, representatives of whom had travelled on the train and explained the training schemes to the delegates.

On the last day of the conference the delegates visited Cambridge where they saw the engineering laboratories of the University and also some of the historic colleges. They were entertained to lunch at Emmanuel College.

Conclusions.—At the sixth and final working session the delegates resolved to recommend to E.U.S.E.C. that a second conference on Engineering Education should be held in 1954 on similar lines to the present one, to continue the work begun. It was also proposed to E.U.S.E.C. that this second Conference on Education and Training should undertake the development of a glossary of terms used in engineering education and training, and that the conference should be authorised to consider the possibility of developing, under E.U.S.E.C. auspices, a permanent conference concerned with engineering education and training. Finally, the delegates agreed that the memoranda presented by each country and the verbatim report of the discussions should be published.

American Symposium on Heavy Presses

(By our American Correspondent)

As part of the 1952 annual meeting of the American Society of Mechanical Engineers, a Symposium on Heavy Presses for Light Metal Forging and Extrusion was held in New York on December 2nd. It may be recalled that the development of both the die forging process and the extrusion process were given considerable impetus by the recent decision of the U.S. Air Force to sponsor a comprehensive programme of design and construction involving heavy press equipment of some 400,000 tons* total capacity and costing about 400 million dollars. The meeting was arranged primarily to emphasise to aircraft designers the need for a greater utilisation of the larger and more complex forged and extruded structural components which are becoming feasible due to the construction of these heavy presses. The papers presented at the symposium were of particular interest as they contained the first officially released information and data with regard to the design, operation and application of these very large presses.

Mr. G. W. Papen, of the Lockheed Aircraft Corporation, presented a paper on " Requirements for Large, Light Metal Forgings and Extrusions in the Aircraft Industry," which discussed and supported these requirements by analysing the effect of the trend in performance on aircraft structure, function and production. The paper showed that large integral structural components satisfied these trends better than a continuation of what the author termed conventional " bits and pieces " structures. As an illustration the following table was given to show the differences between the " bits and pieces " approach and the integrally-stiffened structure now used in the inner wing lower surface of the " Super Constellation " aircraft :

	Conventional design : 120,000 lb gross weight	Integrally stiffened design : 130,000 lb gross weight
Total number of detail parts	1,806	334
Total attachments : rivets, screws, bolts, nuts, &c.	41,000	7,224
Weight of sealing (lower portion of wing only)	80 lb	30 lb
Total weight of structure, including all parts and sealing	1736·9 lb	1442·4 lb

It had been found that the general application of large integral elements in aircraft production offered many important possibilities for cost reduction, increased performance, weight reduction and savings in direct and indirect man-hours and tooling costs.

The author believed that the present trend in aircraft performance would result in a tremendous use for large forgings and extrusions, because large forgings and extrusions should be the most economical method of (1) meeting the space limitations set up in thin wings with high structural loads ; (2) providing minimum weight by eliminating " bits and pieces " ; (3) improving sealing for pressurisation and fuel by eliminating sources of leakage ; (4) improving aerodynamic smoothness, and (5) reducing the man-hours required to fabricate and assemble aircraft.

A paper, " The Design and Construction of Large Forging and Extrusion Presses for Light Metals," was presented by Mr. M. D. Stone, of the United Engineering and Foundry Company. He outlined the development of heavy press equipment up to the time of the last war, during which Germany had built three 16,500-ton hydraulic die forging presses and a 33,000-ton press, which was at present the largest in the world. Two of the three 16,500-ton presses were now being operated in the United States, whilst the third 16,500-ton press and the 33,000-ton press in the U.S.S.R. were now, it was believed, being used for aircraft production. The only large die forging press that operated in the United States during the war was an 18,000-ton machine which did not get into production until 1945. By the end of the last war considerable progress had also been made in extrusion presses. The largest British extrusion press was 6000 tons and the largest in the United States had reached 5500 tons, whilst in Germany one 13,200-ton extrusion press was in operation and two partially completed. One of these two machines was now in operation in the U.S.S.R. and one was being completed for operation in the United States. The following notes dealt particularly with a 35,000-ton vertical die forging press and a 20,000-ton horizontal extrusion press which the author's company was designing and constructing.

The 35,000-ton die forging press then described by the author had a platen area of 24ft by 12ft, corresponding to about 120 tons per square foot, a daylight of 15ft maximum, and open forging press speeds of 10in per second idling and 2½in per second under full pressure. The press could be operated at quarter, half, three-quarters and full pressure without the use of intensifiers and with its eight cylinders and eight columns, consisted essentially of four two-column press units, as far as the top entablature was concerned. This arrangement permitted the full proportional stressing of all columns—the units being free to stretch vertically, independently of one another, whilst being keyed and bolted against lateral movement. These presses, as built, would not be furnished with side cylinders, but the design allowed for the addition of two opposed 5000-ton side cylinders. There were three 250-ton ejector cylinders in the base and one 250-ton ejector in the moving cross-head. The reason for the higher capacity ejector in the bottom of the press was that the major part of all the cavities would be confined to the lower die—the three rams being operated by three separate cylinders, mechanically

* Short tons of 2000 lb have been used throughout these notes.

equalised so that the full 750 tons could be exerted on a single compact piece or distributed over long pieces. The die manipulator table was essentially the bottom bolster, which was 24ft long by 12ft wide by 2ft thick, and operated by a pair of 250-ton oppositely acting cylinders—both acting from one side of the press.

The estimated total weight of the press proper was 10,000,000 lb, with the auxiliary equipment adding another 3,000,000 lb.

It was specified that full pressure could be exerted plus or minus 2ft off-centre along the long axis of the press and plus or minus 1ft off-centre in the lateral direction. This specification meant that proper provision had to be made for a 70,000-ton-ft. eccentric moment, in addition to a full central pressure of 35,000 tons, and it led to the adoption of a hydraulic method of eccentric moment equalisation. In this method the press equalising and lifting cylinders were combined, the cylinders being connected in parallel during idling up and down, and cross-connected in series, when pressing. Four such cylinders were used; one in each corner of the platen, and they were cross-connected diagonally to provide for eccentric loading in any direction at any time. A significant property of this hydraulic equalisation system was that the eccentric moment was equalised by vertical forces only, there being no horizontal reactions introduced. The elimination of significant side forces meant that no substantial loads were imparted on the guide pins because the crosshead was free to float laterally. The operator was given a continuous visual indication of both the magnitude and direction of any eccentric condition during forging. This was effected by projecting a spot of light on a ground glass screen, on which it moved over a diamond-shaped limit area, having a 2ft half-major-axis and a 1ft half-minor-axis. For repetitive work the operator could ascertain from the first attempts how much and in what direction he might shift the dies to minimise the eccentric forging conditions.

In the opinion of the author of this paper there were a number of reasons for the growing preference for hydraulic presses over forging hammers for die forging of light metals, particularly for large work—deeper penetration of forging work, better and more uniform physical properties and absence of the vibration and foundation problems associated with heavy hammers. Experience obtained on the American 18,000-ton die forging press proved that hydraulic presses provided the following additional advantages over the steam or drop hammer: (1) greatly extended die life due to the elimination of impact effects; (2) only small draught angles were required due to single-stroke operation, together with the utilisation of ejector facilities; (3) closer dimensional tolerance could be maintained, as dies were held in alignment during the complete forging cycle; (4) predetermined die temperatures could be maintained on both the upper and lower dies; (5) production rates could be approximately doubled, especially on large and heavy forgings, and (6) complicated forgings requiring undercuts and internal bores could be fabricated. As to relative die life, considerable comparative experience had been obtained on smaller parts, such as pistons, connecting rods, &c., where press die life ranged from 50,000 to 75,000 forgings per die set, as compared to 1000 to 5000 per die set for drop forging. Then, too, because of the absence of impact in press forgings, the possibility of using cast dies instead of forged dies had distinct production possibilities. As to draught angles, due to the requirements of rapid ejection when hammer forging, angles of from 5 deg. to 7 deg. were required, whereas for press forgings angles of 3 deg. down to 1 deg. or less could be used, depending on the depth of cavity—resulting in considerable weight savings. Weight reduction also followed as the dies were kept in alignment by the guide pins throughout the press forging stroke.

Turning to extrusion press design, the author then considered the 20,000-ton press being built as a part of the U.S. Air Force programme. This machine had five 4000-ton cylinders, four acting directly on the main crosshead, and the fifth acting as a separate piercer or as an additional main cylinder. The four main cylinders were situated symmetrically on the horizontal and vertical centre lines of the press—with the piercer cylinder on the longitudinal centre line, and to the rear of the four main cylinders. Each of the main columns was 31½in O.D., some 70ft long and weighed over 200,000 lb. The columns were spaced 100in clear vertically and 132in clear horizontally. The cylinder housing structure, because of casting, machining and transportation limitations, consisted of four units, each carrying a 4000-ton cylinder, and straddling a pair of contiguous columns, the top and bottom units each carrying one of the two 1200-ton pull-back cylinders. Through the centre of the multiple entablature structure was a bore that permitted the free passage of the piercer rod, which moved in adequate guide bearings. The piercer cylinder housing, situated some 45ft behind the main cylinder housing, was held in position by four 13½in diameter columns, situated on the same centre lines as the main columns and the two 400-ton piercer pull-back cylinders were mounted on this same housing. The main crosshead, which carried the pressure stem and permitted the passage of the piercer rod, was made up of two unit castings, arranged in cruciform fashion, and one behind the other. The main press platen for the die or tool container had a large central hole or passageway, through which the extrusion passed on its way down the runout table and through which the tool container moved, together with the butt end of the extrusion, for separation purposes. The clear hole through the tool container itself was such that an extrusion circumscribed by an ellipse 48in horizontally by 32in vertically could pass, the bore through the platen being 68in diameter. The overall length of the press proper was 140ft 8in, with the runout table adding another 150ft. The press was 27ft 1½in high by 24ft 6in wide, its estimated total weight being 7,000,000 lb, with an additional 4,000,000 lb for the auxiliary equipment.

The maximum billet size that the 20,000-ton press would handle was 32in diameter by 80in long, corresponding to a maximum billet weight, in aluminium alloy, of 6000 lb and of 17,000 lb in alloy steel. Providing for a dummy block length of 8in, the billet container length was 90 in. When charging the machine the billets were loaded on to the billet carriage in the "out" position, some 12ft 9in off the centre line of the press, and the carriage then shifted horizontally by a fixed-stroke hydraulic cylinder to bring it into accurate position directly in front of the container. The dummy blocks handled in the same manner were positioned in front of each billet when in the "out" position. To make possible this method of charging, the author pointed out that the maximum stroke of the press crosshead had to be some 180in. The piercer ram had a much greater stroke, of 262in, since the mandrels must project through the dies at least 2in even at the beginning of extrusion of an 80in billet. In order to permit the piercer ram to be stopped at any position in its stroke, when it was operated independently, a motor-operated full-pressure stop was provided. In addition, for use when the piercer ram was adding its force to that of the main crosshead, another motor-operated full pressure stop was provided between the piercer rod and the crosshead.

The billet container had to be designed to handle large billets, at extrusion pressures of up to 100,000 lb per square inch at the maximum diameter, and in excess of 125,000 lb per square inch at diameters down to 20in. The multiply shrunk sleeve container structure weighed about 120,000 lb without the split container housing. The container proper was handled in and out of the press vertically between the two top columns, the 132in clear opening having been provided to cater for future container designs requiring even greater clearances. The outer sleeve of the container had a number of circumferential longitudinal holes for carrying the copper inductor rods, used to maintain a container temperature of up to 1000 deg. Fah. by a combination of 60 c/s induction and resistance heating.

Dealing with the hydraulic power plant for the press the author said it was of sufficient capacity to permit full-stroke operation at the maximum 20,000-ton capacity once every four minutes. It consisted of a number of vertical, high-speed, multi-cylinder pumps, each driven by direct-connected synchronous motors. Rapid movement of the main crosshead during idle stroking was at the rate of 10in per second and was controlled from a 125 lb per square inch prefill system. During pressure stroking a maximum speed of 3in per second was possible at the full capacity of 20,000 tons, increasing to 10in per second at the lowest pressure stage of 4000 tons. A total hydro-pneumatic accumulator capacity of 6000 cubic feet provided for a maximum pressure of 4500 lb per square inch, dropping to 4000 lb per square inch at the end of the longest stroke—the normal full rating of the press being 4250 lb per square inch.

Aluminium Alloy Ingots for Forgings

Mr. T. L. Fritzlen, of the Reynolds Metals Company, read a paper entitled "Metallurgy and Production of Suitable Aluminium Alloy Ingots for Large Forgings and Extrusions." The paper suggested that the use of larger and more complex aluminium alloy structural members in the aircraft of the future depended initially upon larger aluminium alloy cast ingots suitable for upsetting, rolling, extruding or forging becoming available. The "strong" aluminium alloys, corresponding to the American "14S" "24S" and "75S," specifications, were at present produced commercially in solid ingots up to 16in diameter, weighing 2800 lb.

In the opinion of this speaker two processes could probably be developed for casting large sizes of "strong" aluminium alloy ingot weighing up to 12,000 lb each, that would be suitable for rolling, forging or extruding. These two methods of casting were known in the United States as the "water-dipped" and the "direct-chill" processes. The water-dipped method consisted of filling a heated, relatively thin sheet metal mould with molten aluminium alloy at an optimum temperature and then lowering the filled mould at a controlled rate through a water spray whilst supplying heat to the upper or unsolidified portion of the aluminium alloy. The more recent direct-chill process consisted of introducing molten aluminium alloy, at an optimum temperature, through a pouring spout into an open-ended, short, thin, water-cooled sheet metal mould. The high-conductivity metal mould was closed temporarily at the bottom end by means of a metal bottom block. After solidification of the aluminium alloy first poured into the mould, the bottom block and along with it the solidified and solidifying portion of the ingot was lowered vertically through water sprays. The amount of molten metal introduced into the mould was synchronised with the rate of lowering the solidifying aluminium alloy ingot.

Progressive bottom-to-top solidification and rapid freezing were obtained in both the water-dipped and direct-chill processes. However, the direct-chill process, as its name implied, provided the faster chilling and consequently the more desirable metallurgical structure, such as finer grain and constituent size. The direct-chill process was used to a greater extent than any other casting process in the American aluminium industry as it gave higher quality, higher production rates and lower costs.

A paper on "Large Forging Press Operations and Production Problems" was given by Messrs. G. W. Motherwell, J. R. Douslin and A. L. Rustay, of the Wyman-Gordon company, which operates the 18,000-ton die forging press.

The final paper of the symposium dealt with "Large Extrusion Press Operation and Production Problems," and was presented by Mr. T. F. McCormick, of the Aluminum Company of America, who said that the first of the very large extrusion presses under the U.S. Air Force programme was now being installed. This press had a rated capacity of 13,200 tons and the inside diameter of its cylinder liners would vary from 15½in to 29½in and be of sufficient length to handle ingots 70in long. Manufacturing limits for solid shapes produced with this press and its planned auxiliary equipment had been laid down for a maximum length of heat-treated aluminium alloy extrusion of 90ft, a maximum weight of 2300 lb and a maximum

cross section to fit within a circumscribing circle having a diameter of 23in.

The speaker said that much experimental work had been done on the production of integral rib-stiffened aircraft wing panels by extrusion and several schemes had been tried with good results. The extrusion part of the problem was relatively simple, but straightening to the necessary flatness presented more difficulty. With the presses at present in use the limit for such extrusions was a width of about 27in, but with the installation of the 13,200-ton extrusion press it was conservatively estimated that this could be increased to 34in.

Productivity Team Report on Machine Tools

THE report of the productivity team on metal-working machine tools has now been published. This team was made up of fifteen members, with Mr. R. D. G. Ryder acting as leader and Mr. F. H. Harris as secretary.

The terms of reference covering the visit to the United States were as follows : to confine inquiries to metal cutting and abrading machine tool manufacturers ; to limit investigations of such firms to their activities as producing units ; to examine the activities of some efficient American machine tool manufacturers ; to judge whether any of their methods or activities could with advantage be adopted by any British machine tool manufacturers, and to report on any such methods or activities ; to obtain information about the American machine tool industry in general which may be of value and interest to the British machine tool industry; and to prepare a report setting forth recommendations for increasing productivity.

The report points out that machine tool industries of both countries have a very mixed make-up, each consisting of a varied assortment of individual firms, large, medium and small, there being in each a very wide gulf between the best and the worst, although the best in one country is not greatly different from the best in the other.

Visits were not confined to those American machine tool companies that might be regarded as the " high spots " ; the team visited what was considered to be a fair cross section of the industry, from a firm with about twenty operatives to one with about 5000. This gave a better and more balanced appreciation of the American industry than if visits had been limited to the " high spots," and the opinion was confirmed that size and reputation are not necessarily a guarantee of efficiency.

Because of this similarity between the two machine tool industries the team found it extremely difficult to convey the right comparison of their relative positions by only recommending that the British machine tool industry might copy certain practices from the American industry. It decided therefore to consider recommendations for increasing productivity as applying to the machine tool industries of both countries, the recommendations being based on personal and team knowledge of both these industries.

Before sailing for America, the team spent two weeks visiting eleven British factories to give the members an opportunity to broaden further their background knowledge of the industry in Britain.

In five and a half weeks spent in America, twenty plants were visited, usually by the complete team, but in some cases by as few as one or two members only. The particular plants visited represented a cross-section of the machine tool industry, some being among the largest and some among the smallest.

Each plant was toured by the team, split into small groups accompanied by knowledgeable guides ; points of interest were noted and questions asked. Subsequently the various specialist members of each plant were questioned on their own particular subjects by groups allocated for that purpose ; in a few instances the team did not divide into groups, in which event the coverage was not so wide.

As the team did not spend more than one day at any plant (in a single instance a small group returned to a plant for a second day) it was impossible to go very deeply into any of the activities, members electing to get a general picture of all activities connected with the running of the plant rather than a completely detailed picture of a very limited part of the total activity.

Group reports were prepared, agreed, duplicated and circulated to all team members after each visit.

A number of talks took place with people connected with, or interested in, the machine tool industry who were not members of the plants visited ; in particular Mr. Tell Berna, of the National Machine Tool Builders Association, and Mr. Burnham Finney, editor of *The American Machinist*. These talks gave a useful background picture of American industry in general and the American machine tool industry in particular.

Any Press articles or pamphlets dealing with the machine tool industry that could be obtained were read by some or others of the team and many detailed and sometimes lively discussions took place.

It was felt that the tour, supplemented by the afterthoughts and correspondence of the succeeding months in Britain, gave the team, as a whole, a fair appreciation of the present position and future possibilities of the machine tool industry as a producer of machines.

In the report the conclusions and recommendations of the team are summarised as follows :—

Conclusions

There are no outstanding differences between the American machine tool industry as we saw it and the British machine tool industry as we know it. The best we saw in America is certainly no better than the best in Britain, and the range between best and worst is probably quite as wide in the U.S. as in Britain.

In neither country is the productivity of the industry as high as it should reasonably be.

In both countries sales are limited by high prices.

The machine tool industries of both countries are in danger of losing large proportions of their markets unless they rapidly increase their productivity.

Our conclusion, based on the cross-section of the industry we saw in America, is that productivity in the American industry is, on average, higher than the productivity in the British industry, this being principally a result of : wider and better application of the science of " design for production " ; more realistic approach to " accuracy " and " finish " ; greater use of handling facilities ; better machinability of the steels and cast irons used ; more accurate balancing of plant capacity and planned load ; and better servicing of the machine operatives.

The American operative works no harder than the British operative, but he gets a better standard of living for his efforts. This better standard is only partly justified by the slightly higher productivity of the industry ; in the main it is subsidised by those industries which have given America her prosperity.

The operatives in piece-work shops in America work harder than the corresponding operatives in non-piece-work shops.

Apprenticeships are not considered necessary for the majority of production jobs in the American industry ; " green " labour is quickly trained to competence on a single job basis, and is then eligible for full union recognition and membership. These operatives, on their particular jobs, are at least as good as the full apprenticeship craftsman in Britain, who generally insists on remaining on one particular type of job for most of his life.

Although surface indications might give the impression of happy relations between management and labour, we formed the definite opinion that, basically, relations could not always be described as happy.

The " seniority " clauses in company-union agreements, providing generally for " last in first out " employment, produce stable labour force conditions ; loss of seniority through changing jobs might mean unemployment and does increase uncertainty. A distinct disadvantage is that good operatives may have to be " stood off " before not-so-good operatives.

Although the individual company-union negotiations and agreements current in America make for a better understanding of local conditions and take such conditions into consideration, the set-up is inherently less stable than the British set-up which depends principally on national negotiation.

There are as few signs of industry-wide rationalisation in the American as in the British machine tool industry.

Recommendations

Short-Term.—To revert to " wartime " finish both as regards paintwork and metal finishing.

That grinding and finish-turning cuts, for appearance only, should be eliminated.

That a realistic and practical appreciation of the economics of accuracy should be developed and the broadest possible tolerance, commensurate with correct functioning, should be allowed in every instance.

That inspection costs should be reduced by applying simple statistical control to the amount of inspection carried out on any individual batch of components.

To specify a softer cast iron for the general run of machine tool castings, to ease machining.

To arrange for many more inter-works visits, especially by foremen and production engineers. These visits should not be confined to machine tool plants but should cover industries right up to the best mass production plants.

Medium-Term.—To educate customers in general to judge machine tools on performance, not on appearance.

To apply the principles of simplification and standardisation energetically and ruthlessly both within each company and within the industry as a whole. Then to allow full scope to specialisation, especially of components.

To allow of a more utilitarian basis for the preparation of drawings and save considerable man-hours in drawing-offices with no loss to the manufacturing departments.

To introduce " productivity-mindedness," initially to the designs side of the industry, from some high-productivity industries.

Each firm to prepare the statistics which will enable programme requirements to be equated to the real plant capacity.

Long-Term.—To reduce considerably the number of independent manufacturing companies in the industry, by absorption, amalgamation or any such means that will allow of greater standardisation and concentration.

To examine, develop and implement a system of " standardised unit " construction for the bulk of machine tools, aiming at volume production of industry-wide common units to manufacture low-priced, simple machines.

Painting Aluminium.—We have received from the Aluminium Development Association, 33, Grosvenor Street, London, W.1, a copy of " Information Bulletin No. 20, Painting Practice for Aluminium," price 2s. Hand, vapour and immersion methods of cleaning and degreasing are briefly outlined, followed by a section dealing with pretreatment in which reference is made to acid chromate, phosphoric acid and alkali chromate processes, together with a note upon " etch primers." The choice of a paint system is considered for single-coat systems for decoration and protection and for multi-coat systems for exposed positions. In the first group there are references to stoved enamel, vinyl and other finishes, while in the second group paragraphs deal with painting for marine and industrial applications, structural work and castings. The bulletin concludes with notes on the repainting of small and large components and structures.

Research and the Gas Turbine*

By HAYNE CONSTANT, C.B.E., M.A., F.R.S.

In this twenty-first Andrew Laing Lecture a study is made of the philosophy that has guided the outlook of some of those working on gas turbine research during recent years. It is shown how work has been affected by their belief in the importance of timing, in the simplification of design and the concentration of effort.

IN a field as broad as that of the gas turbine, and one in which the extent of the possibilities had not been properly explored, it was impossible to lay down a programme of research by the simple process of picking on the essentials. We were not sure what the essentials were. We therefore started to clear the ground a bit by making a list of the things we would not work on. I, personally, following my belief in the importance of concentration of effort, got a lot of satisfaction out of drawing up this list, and I add to it with great relish whenever possible. I do not think I should tell you all the items on my list, but I will give you some of them.

(1) We objected to the use of heat exchangers for turbine-driven aircraft on the grounds that the world was not large enough to justify their use, and we decided to do no work on them. This decision may seem a blinding glimpse of the obvious to-day, but it was strongly contested at the time, and in fact much money was spent in trying to develop an aero-gas-turbine propeller engine with heat exchanger, in vain.

(2) I had formed an adverse opinion of the possibilities of using ceramic materials for blades about fifteen years ago. I obtained sufficient support in the Royal Aircraft Establishment for a decision to attempt to attain high temperatures by the use of cooling rather than by the use of uncooled materials such as ceramics.

(3) About ten years ago we, who were then at the Royal Aircraft Establishment, had abandoned our advocacy of the propeller turbine, and had agreed with Sir Frank Whittle that jet propulsion was the most effective way of propelling an aircraft. We have since found no reason to change our views, and so we put propellers on our little list.

(4) We have not worked on gearing or on bearings, partly because they are components common to most types of machinery and not specifically related to gas turbines. Moreover, they do not usually introduce serious problems in the gas turbine, and the future of this type of power plant cannot be said to be dependent on the elimination of bearing or gearing troubles. Finally, there are already many skilled and experienced workers in this field.

(5) Although most of my earlier work and experience was on centrifugal and displacement compressors, it became pretty clear to most of us many years ago that neither of these types was likely to be as satisfactory for aircraft use as the axial. At the end of the war our interests were broadened to include all forms of gas turbines and it became necessary for us to decide on the best forms for land and sea. If we had not already committed ourselves to the axial type for the air, it is just conceivable, but I think unlikely, that we would have decided on the centrifugal as the best for land and sea. As it was, our desire for concentration of effort and the elimination of unnecessary problems led us to adopt the axial as the most likely machine to use for almost all gas turbine applications.

(6) We decided against working on closed cycles on the grounds that once the cooled turbine was developed the maximum temperature of the open cycle would rise above that of the closed cycle and give a higher efficiency. We objected, moreover, to the greater complexity and complication of the closed cycle for a power plant, the main point of which, after all, was its simplicity.

(7) Finally we turned our faces against very small engines because we believed in the teachings of Osborne Reynolds and felt that, both on aerodynamic and mechanical grounds there was a minimum size below which satisfactory engines could not be made.

Having completed the rather negative process of deciding what not to do, we had to take one further step before we could crystallise our programme of work. This step—and it is one which we repeatedly take—is the process of trying to visualise the layout and thermodynamic cycles that are likely to be used for different applications, to assist us in anticipating the problems that the gas turbine is likely to throw up. It has become necessary for us, therefore, to spend a certain amount of time making comparisons of the various possible forms of engine for different applications. This is a most interesting occupation, but also a most dangerous one. Quite a small error in the assumptions made can be magnified in the ensuing argument and lead finally to totally wrong conclusions. An even more potent source of error can be due to the effect of faulty judgment in deciding what to take into account and what to neglect. A good example of this is to be found in the vicissitudes of the ducted-fan engine. In the early days several engines were built with ducted fans having their blades mounted on separate low-pressure turbines. These proved unsatisfactory because it was extremely difficult to get the air into an intake near the rear end of a nacelle and also because

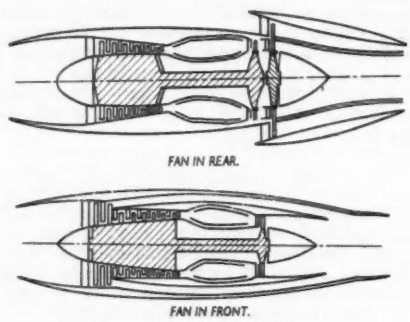


Fig. 1—The Ducted Fan Engine

the mechanical layout invited bearing and sealing problems. We made a new assessment of the problem in 1946 and decided that a better arrangement would be to place the ducted fan in front of the engine so that it feeds air into the main compressor (Fig. 1). This opinion was probably right, but where we went astray was to conclude that the load of the fan on the main turbo-compressor would be so great that acceleration would be prohibitively slow. Looking back we now see that had our judgment been better we would not have passed over this most promising type of engine simply because we could not at that time see the answer to the acceleration problem—an answer which incidentally we had already been advocating for other types of engine.

Nevertheless, in spite of the difficulty and dangers of making comparative assessments of different forms of engine, such assessments are absolutely necessary. If one is going to be wrong one might as well have a good reason for it ! An assessment gives one the facts and gives one's judgment a chance to show what it is worth. In our own case, very aware of how easily we could delude ourselves and others, we have on many occasions ignored our own reports and simply said, " We don't believe it." As a result of this unbelieving spirit we have, I think, " dropped remarkably few bricks."

The comparative assessment of aero-engines is a very complicated business. The airframe and the engine interact on each other to such an extent that it is not sufficient to compare the bare engines on the basis of their weight and fuel consumption. Different engines may have different frontal areas and drags, and react differently to changes in altitude and forward speed. They may also have different reserves of power for take-off and short periods of boost. The only satisfactory method of comparison is that of comparing the performance of hypothetical aircraft each powered by the different engines which are to be compared. The aircraft is thus tailored to the engine, and the engine which gives the best aircraft performance is the best one.

Such a process is involved and takes a long time. Even so, it is only an approximation to the truth. It does not take into account, for example, the advantages that one form of power plant may offer in simplicity, reliability, ease of installation, long life, freedom from vibration and cheapness. And so when the assessments said that jet propulsion was only suitable for short endurance aircraft such as fighters, and that piston engines were best for very long ranges we simply refused to believe them. We have consistently held the view that, in spite of what all the figures and calculations say, jet propulsion is better than propeller propulsion. This again is almost accepted by the aircraft world to-day, but ten or even five years ago we were regarded as being rather unrealistic.

The examination that we made of the application of the gas turbine to railway traction led us to the conclusion that what was required was a simple form of engine running on liquid fuel and driving from a separate power turbine through a mechanical rather than an electrical transmission. Tests that we made to determine the torque characteristics of multi-stage turbines showed that no change-speed gearbox would be required. We thought it likely that such locomotives would prove more suitable abroad than on the railways of this country, where high traffic densities are forcing us towards electrification. It is too early to say whether these views were correct.

We foresaw the use of gas turbines for standby and peak load uses in works power stations using simple cycles with efficiencies of up to 25 per cent. We thought it unlikely that there would be much scope for large base load power stations unless some simple means of coal burning could be devised.

We have always been very optimistic about the likelihood of the widespread application of the gas turbine to marine propulsion, but rather vague about the form which the engine should take. This, I think, springs from a consciousness of the extent of our ignorance of marine affairs. When, for example, we note that marine architects often design their engine-rooms much larger than is necessary because of a rule laid down before any of them were born, we realise that our mental planes do not intersect.

The concept that we first arrived at for the large marine engine was that of obtaining the maximum possible efficiency and flexibility by dispersion. We envisaged a power plant of the double-compound type with heat exchangers and intercoolers, the various components of which were connected together by trunking. Examples of such power plants have since been produced by various manufacturers. To-day we are not so sure. We believe that weight and bulk should mean more to the marine engineer than in fact they do. We have a growing feeling that the integral power plant, consisting of a single piece of machinery like a diesel engine, may in fact be the right solution. Such an engine might be a little less efficient than its dispersed competitor, but it would be vastly lighter, cheaper, and more compact.

There are so many possible arrangements and cycles that can be used in the gas turbine that a great amount of exploratory work extending over several years was needed before we could be sure that we had found the best answer for each duty. In the course of this work we explored over a hundred cycles and variations of them and had to work for as much as six weeks on some of them in order to determine the engine performance under part-load conditions.

This process is a continuing one ; new cycles, new modifications to old cycles, detailed changes in aerodynamics, such as boundary layer bleeding ; in mechanical design, such as adjustable turbine nozzles ; and in thermodynamics, such as bypass reheat, are continually making neces-

* " The Application of Research to the Gas Turbine," North-East Coast Institution of Engineers and Shipbuilders, Newcastle upon Tyne, December 12, 1952. Abridged.

sary the revision and reworking of performance calculations.

As a result of all this work we have, we believe, obtained some idea of where the gas turbine is likely to be used and what form it will take. From this we have formed our own views on the problems and difficulties that are likely to arise. It is on these that our programme of work has been based.

The N.G.T.E. Programme

We have always believed that the gas turbine is essentially an aerodynamic machine, and our programme of work has faithfully reflected this belief. At the front of our aerodynamic programme has been our work on the deflection of air by a cascade of blades, since it is on this deflection that the performance of compressors and turbines depends.

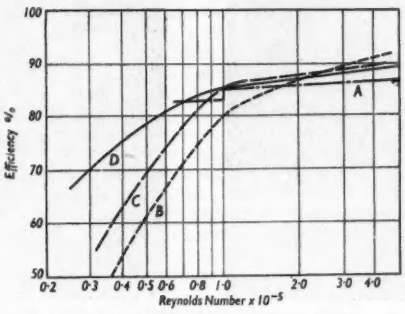
In 1945 our attitude towards the general problem of flow through blade cascades was one of great optimism. Such optimism is a common phenomenon at one stage or other of a scientific investigation, and is usually due to a failure to appreciate the true difficulties of the problem. In this instance, although we had, for example, considerable success in correlating the overall performance of the F.2 axial compressor with cascade data, we had not realised that, owing to its high hub ratio, this compressor represented a particularly easy subject.

Our general philosophy for the design of axial compressors and turbines was based on the use of two-dimensional cascade test data, corrected for three-dimensional effects. We believed that it should in time become possible to produce a family of curves giving the two-dimensional performance of a blade profile when arranged in cascade with any desired pitch chord ratio, stagger or incidence. From these pictures, one for each profile, it should be possible to pick the desired design conditions, correct for three-dimensional effects and thus obtain the performance of a single-stage compressor. We retain this belief to this day with one great modification. We have already produced the integral picture for the performance of the aerofoil which we know as C.1, under any conditions of operation and we have proved that its use accurately predicts the single-stage compressor performance. Where we have failed and where we have had to modify our outlook is in the application of our cascade data to compressors of small hub ratio, having, that is to say, blades which are long in relation to the compressor diameter. In compressors such as these the radial flows which take place make it impossible with present knowledge always to predict the position of the surge line.

Once the single-stage performance is known the overall multi-stage performance is predicted by the addition of the appropriate number of stages. We used to do this by simple addition, in the belief that one stage would act independently of the presence of the adjacent stages. We now know that the tests on which this belief was based were misleading and that we have to apply a correction, known as a variable work-done factor, to take account of the fact that there is a progressive change through the compressor of the variation of axial velocity with radius ; or, in other words, a thickening of the boundary layer takes place.

In some respects we have during the last five years made great progress in a circle, returning approximately to our starting point. For example, all our early work on compressor blading was done on blades with a circular arc backbone. Simple theory, confirmed by misleading wind tunnel tests then made it clear to us that a change to a parabolic arc camber line would give better performance at high Mach numbers. We therefore started new programmes of cascade testing to give us the necessary basic data on parabolic arc blades. It was only after a more rigorous theoretical approach had been made, confirmed later by high-speed testing, that we realised that the parabolic blading, while giving us higher choking flows, had appreciably lower critical Mach numbers ; so we returned to circular arc blades. Unless some new base profile is introduced the basic data now available are probably adequate and little further routine wind tunnel testing will be necessary. Our wind tunnels are therefore being diverted to other uses and our attention is being concentrated to an increasing extent on the performance of rotating machinery.

Perhaps the biggest unknowns in axial compressor design to-day are, first, the effects of Reynolds number on performance, effects which we now know to be dependent on the blade design and arrangement (Fig. 2) ; and, second,



A, 1941 : A. R. Howell's original assumption, based largely on intuition.
B, 1946 : The only data available by this date were of German origin, and we just didn't believe them.
C, 1949 : First experimental data of our own, based on 106 compressor and cascade tests. We still didn't believe them.
D, 1950 : Based on corrected 106 compressor results. We use these data and believe they may not be very wrong.
1952 : A new attempt to obtain more accurate data is now in full swing.

Fig. 2—The Effect of Reynolds Number on Compressor Efficiency

the conditions which determine the position of the surge line. This last problem is a most mysterious one. The great bulk of compressors develop their design capacity and surge at predicted mass flow. But occasionally and for no apparent reason, someone designs a compressor with a surge capacity as much as 10 per cent above or below the predicted value.

In spite of these rather frank remarks, it must not be concluded that no progress has been made. In spite of the false starts, the changes in direction, the failures of judgment and of understanding, which are inevitable in work designed to extend the frontiers of knowledge, great progress has nevertheless been made. The overall result of the increase in knowledge which has been attained is that the polytropic compressor efficiency has risen from about 88 per cent to about 91 per cent and the maximum pressure ratio attainable from an axial compressor, which was about 4½ : 1 in 1945, is now over 7 : 1, being greater than is required for most gas turbine applications. We now have the essential data on which the aerodynamic design of compressors and turbines is based.

The other essential component of the gas turbine, the combustion chamber, also has its problems. Combustion is a particularly difficult subject to study, in that it involves aerodynamic, chemical and physical problems. Its study is not, of course, an occupation reserved for the gas turbine engineer. It has been a preoccupation of many organisations and interests long before the first gas turbine ever ran. The only

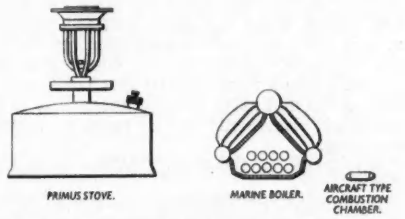


Fig. 3—Combustion Chambers with Heat Release of 20,000 h.p.

excuse for the turbine engineer's entering this field is that he has introduced all the old problems in a more acute form and, at the same time, offered a new philosophy or outlook to assist in dealing with them. He could, of course, have taken a primus stove or the blow lamp as they stand, but he preferred to say " we must reduce our combustion chamber to one hundredth of that at present possible and here is a new technique to enable us to do it " (Fig. 3). Or he could have burnt heavy oil in the same way as it has been done under marine boilers for several decades. But the gas turbine engineer wanted less space and a higher temperature and so again decided to make a fresh start.

He has therefore become very interested in combustion and, in order to understand it properly, he has turned to a study of its fundamentals.

An understanding of the processes of combustion involves a knowledge of a variety of processes, for many of which the basic data are not in existence. One of our tasks over the last few years has therefore been that of filling in these gaps in our knowledge.

I only mention a few of the many researches on basic combustion phenomena that have been undertaken. We have developed an experimental technique for measuring the spontaneous ignition temperatures of fuels. From this work we have established the ignition delays for a variety of fuels under turbine operating conditions and measured their variation with pressure. A fairly complete picture of the mechanism of evaporation of a liquid fuel droplet has been built up. It has, for example, been found that at high temperatures the effect of fuel volatility is negligible, while at low temperatures its effect dominates the whole process. Again, it has been shown that the drag of a droplet increases upon burning at low Reynolds number and decreases when the Reynolds number during combustion is high. The formation of cenospheres and coke-like particles as the result of the combustion of heavy fuel has been demonstrated and explained. The effects of air vitiation upon the processes of combustion have been determined and their influence on the design of a chamber with exhaust gas recirculation have been demonstrated.

Apart from our work in providing basic data, of which I have given examples drawn from the aerodynamic and combustion fields, we have worked on a variety of more practical problems selected in accordance with the general philosophy outlined above.

An important problem, and one which is in every respect suitable for being worked on at the Establishment, is the cooled turbine. Although considerable thought had for some years been given to the problem of turbine cooling, it was not until late 1945 that we were in a position to make a serious start. At that date we were aware of the work done in Germany during the war. We were not attracted by it partly for obvious psychological reasons and partly on technical grounds which I believe to be valid.

We started the work with a clear preference for the use of water cooling. This was influenced by some preliminary experiments we made with water-cooled Perkins tubes in a rotating rig. Within a year our attitude had changed to one in which we believed that liquid cooling—using a substance other than water—was the most desirable method, but that air cooling was very much easier. When the moment came for a decision to be made we decided that the first blades to be tested should be air cooled with the air passing radially through the blades, and that these should be followed up by blades internally cooled by water in Perkins tubes.

Looking back on the discussions we had during the early days of this work, I am struck, as I have been struck before, by the way the human mind refuses to accept the correct solution to a problem until it has laboriously examined in turn all the alternatives, which in retrospect looked merely silly. I can well remember how for months I was firmly convinced that the cooled blade was going to be a solid metal blade with a ceramic sheathing to give a temperature drop and protection from oxidation, the heat being removed by cooling in the rotor. This and many other schemes had to be considered and rejected before we reached the methods at present in use.

During the last five years much ground has been covered and much information has been gained. We have tested various forms of blade in wind tunnels up to 1200 deg. Cent. in order to determine the heat transfer coefficients, both gas-to-metal and metal-to-air. We have carried further our experiments with Perkins tubes, we have tested a turbine with blades internally

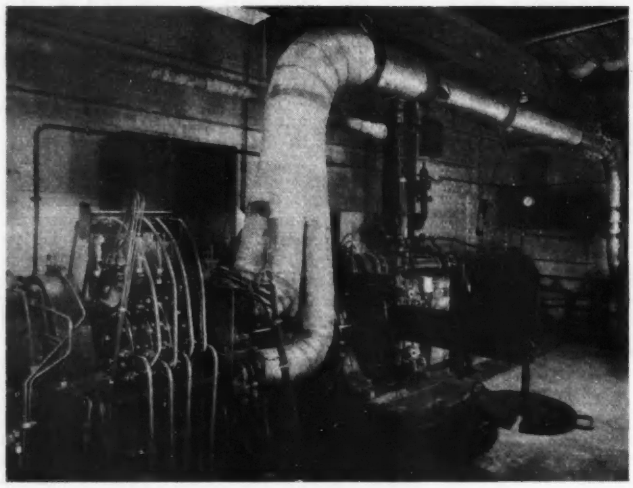


Fig. 4—Water-Cooled Turbine

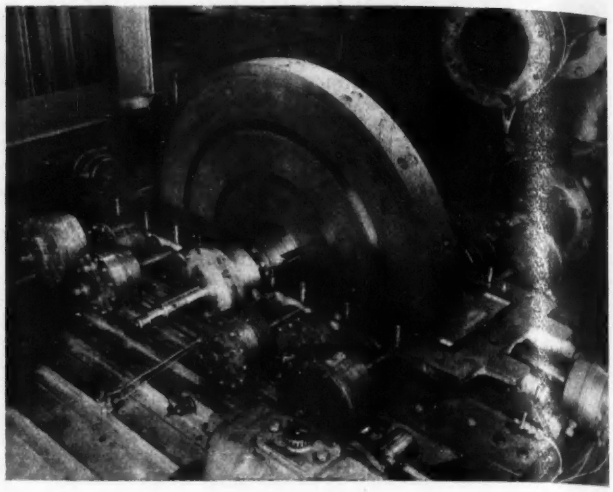


Fig. 5—Rotary Heat Exchanger

cooled with water (Fig. 4), another with blades externally cooled by water sprays, and yet another with blades internally cooled by air. We have developed combustion chambers operating at temperatures up to 1200 deg. Cent.; we have experimented with ducting and chambers having cooled liners made from porous and other materials. After all this experience our original view, that liquid cooling is better than air, but more difficult, still holds good.

The work has been remarkable for the consistency with which our views have been held, the principal inconsistency being the way in which our judgment as to the most important problem has shifted, back and forth between the problem of manufacture of a cooled blade, on the one hand, and the problem of cooling large areas of stationary ducting without excessive heat loss, on the other. Our current view is that the problem of cooling ducting has now been solved, but we have yet to see a design for an inexpensive but efficient cooled blade.

The work that we have done on heat exchangers, on the other hand, may be cited as an example in which our attitude of mind has changed considerably. When we commenced work on heat exchangers in 1946 we felt that the conventional recuperator of shell and tube or plate construction did not offer problems for which research might provide solutions. We therefore decided to start work on the rotary regenerative heat exchanger.

This work is an example of the technique of "having a bash at it." A preliminary theoretical study of the possibilities of this kind of heat exchanger had made it clear to us that there was certainly a sealing problem; but the problem was one that we felt straightforward development could deal with. We were more concerned with the chance of there being some other unguessed-at difficulties, which, when revealed, might make it clear that this type of machine was impracticable. And so, having decided that we could not foresee the problems and deal with them separately, we decided to make a heat exchanger and see what happened (Fig. 5).

What did emerge from the practical test was that there were no unexpected difficulties. Fouling, even when running on heavy fuel, could be controlled by soot blowing; the heat transfer data were readily obtained and could be reconciled with theory and mechanical reliability was satisfactory. Only the problem of sealing remained.

In conformity with our principles we had been reluctant to embark on the problem of sealing, which we had considered to be a development problem more appropriate to industry. Our early progress reports on the work we were doing did not, however, arouse the interest that we had hoped, and it seemed clear to us that industry, sceptical as ever, was awaiting a more practical demonstration. We decided, therefore, that we would have ourselves either to solve the sealing problem or to demonstrate very clearly that it could be solved. We have now carried this work as far as our resources will allow and have convinced ourselves that this problem has been solved. The immediate future will show whether we have succeeded in convincing other people.

Now that we have had some years' experience of heat exchangers, a change in our attitude towards them may be detected. In order to explain this I must for a moment go off at a tangent. The minimum weight and bulk of any vehicle is very dependent on the weight and bulk of its power plant. This is well recognised in the aircraft world and the fact is exploited to the full. Road transport has already begun to appreciate the point and to realise that by saving engine weight and bulk you indirectly save fuel by reducing the weight of the vehicle. But in the railway and marine worlds I do not think that it is realised how much smaller the vehicle could be made if more attention were paid to the design of the power unit.

The most ravenous consumer of bulk and weight is the heat exchanger. Until recently we had to accept it as the only method of giving good fuel consumption. Now, however, the cooled high-pressure engine is on the point of emerging as a competitor and one which we believe is likely in the long run to win the day. We have therefore brought our work on heat exchangers to an end.

Conclusion

Before I come to my conclusion I should like, if I may, to draw a moral. It is very easy to make experiments but very difficult to deduce worthwhile knowledge from them. In a field in which the problems to be solved greatly outnumber the facilities available for their solution, there is, paradoxically, a positive virtue in inaction—provided, of course, that inaction leads to more thought. It is only by the greatest possible use of really level thought that we can pick out the very few things that are worth doing and refrain from the great bulk of possible actions which are nothing more than beating the air. By such restraint we can ensure that our limited resources are used so that when we do take action and make an experiment there is an increased likelihood of a positive answer emerging.

My moral is therefore, "When in doubt, don't."

It is always very difficult to know what to put in and what to leave out when one is giving an account of the activities of an organisation. I have avoided this difficulty by concentrating on the philosophy that has guided us, selecting items of research primarily as illustrations of our outlook. I have therefore made no mention of many pieces of work, which, important though they may be in their end results, do not appear relevant to the theme I have been laying before you.

It is, of course, well known to everyone that good judgment, intuition or whatever you like to call it—this quality, which is essential for the successful research worker and not at all a bad thing for other people as well—must be based on the correct interpretation of experience. This experience, so far as we have been able to gain it at all, has been built up on a mass of theoretical and experimental work, much of it of a rather humdrum character. It is based on the tests of many engines, of dozens of compressors, turbines and heat exchangers, scores of combustion systems and hundreds of minor accessories. All this background of experience, when boiled down and crystallised out, affects one's outlook and forms one's philosophy.

You will have noticed from what I have said that our own outlook has been directed always towards the reduction of complexity. We have tried to concentrate our efforts, to eliminate the unessential, to narrow the field of inquiry. If my own philosophy—my attitude towards machinery—had to be expressed in two sentences, I would borrow one from Henry Ford, "Simplify and add lightness"; and one from James Watt, "In all things, but proverbially in mechanism, the supreme excellence is simplicity."

Corrosion Resistance of an Aluminium Coating

The British Iron and Steel Research Association has recently issued a short report upon an example of the prolonged protection afforded to a steel building by a sprayed aluminium coating. The building concerned is the test house of Brown Bayley Steels, Ltd., Sheffield; it is about 60ft long by 25ft wide and 15ft high except at one end, where the height is 20ft. Steel plates ½in thick were used for the walls, which have an area of about 2000 square feet, and the outer surface was grit blasted and then sprayed with aluminium, after which a 3ft high dado was covered with two coats of black bituminous paint and a coat of lacquer. From 1938, when the work was completed, until the war, the walls were untouched and then they were encased in sand revetment to a height of 10ft, when the building was used as a strong point. According to the report the coating was found virtually intact when the revetment was removed in 1946 and it was considered sufficient to repaint the building; two coats of bituminous paint were applied to the dado and above this two coats of aluminium paint. In June, 1952, the Protective Coatings (Corrosion) Sub Committee of the Association reported that it found the sprayed aluminium coating in very good condition although slight rust staining and small patches of rust were observed, including a band 3ft wide over a window where 10 per cent of rusting had occurred. The report states that it will be advisable to repaint at an early date since fifteen years is about the maximum life of a sprayed aluminium coating in a highly corrosive works atmosphere.

Industrial and Labour Notes

Coal Miners' Wages

Discussions on wages were resumed last week by representatives of the National Coal Board and the National Union of Mineworkers. The union has recently put forward a claim for an increase of 15s. a week for all day-wage earners in the industry, but after giving it careful consideration the Board felt unable to offer more than 6s. a week on the national minimum wage, which offer is not acceptable to the union. After last week's discussions the National Coal Board issued a statement expressing regret at the inability "to bring the recent series of meetings to an agreed conclusion."

This statement sets out the present situation, saying that its starting point was the union's claim last summer for an increase of 30s. a week for all workers in the coal mining industry. That claim was advanced only six months or so after an agreed settlement at the end of 1951, which gave the men a substantial wage increase costing the National Coal Board about £21,000,000 a year. After negotiations had proved unfruitful, the claim for 30s. a week was referred to the industry's National Reference Tribunal, which, after hearing all the evidence, made an award last October that no wage increase was justified. At the same time, the Tribunal stressed the desirability of a reconstruction of the wages system. Notwithstanding the Tribunal's award, an agitation began in some coalfields for some immediate increase in wages. The Coal Board suggested to the union that, pending the formulation of a revised wages structure, the position might be stabilised by an arrangement that there should be a continuation of the standstill on piecework advances for a further twelve months, that an advance of 6s. a week on national minimum wages should be accorded to help the lowest-paid men; that the Board and the union should endeavour to reach agreement on a revised wage structure for daymen by the end of March; and that the union would agree to continuing the arrangement for Saturday working for a further twelve months from April 30, 1953.

That arrangement was not acceptable to the union, which then came forward with the claim for an advance of 15s. a week for all daymen. In reaching its conclusions about the claim, the Board says that it felt bound to consider several factors. Its view is that there have been no substantial changes in circumstances to justify a departure from the basis of the National Tribunal's award. The Board has also pointed out that, in the last six months of last year, costs of production rose markedly, coincident with a fall in output per manshift, and attention has also been drawn to the necessity to recoup the substantial deficit which the Board will have to carry forward from the end of 1952. Furthermore, there is the necessity in the nation's interest to keep the price of coal down as far as possible, the Board already having to budget for an increase in production costs, largely due to increases in wages costs.

The statement ends by saying that, in the course of the negotiations, the union offered, jointly with the Board, to intensify efforts to increase production and efficiency through the use of the consultative machinery or, if necessary, by setting up special machinery. The Board has welcomed this offer and hopes also that the union will co-operate with it in further measures to minimise unconstitutional stoppages and go-slow movements. Throughout the recent negotiations the Board has made it clear that it is determined to press on with the formation of a revised wages structure, first for daymen and later for pieceworkers.

Economic Policy

The statement of Lord Balfour of Burleigh, chairman of Lloyds Bank, Ltd., which accompanies the annual report, emphasises many matters which are pertinent to the present economic situation. In the course of the statement, Lord Balfour suggests that this country's greatest need is to speed up the production of those capital goods—mainly engineering products—which are so urgently required both for export and for the modernisation of our own factories. That, Lord Balfour points out, cannot be done without a major change in the pattern of production; nor can it be done without some reduction in the demands made upon our resources by home consumption, in the widest sense. To promote the necessary shift of resources and to create the necessary saving are, in Lord Balfour's opinion, the supreme tasks of financial policy at this juncture.

Nor, the statement goes on, is it merely the Budget which is involved. The finances of local authorities, the price policies and investment programmes of the nationalised industries, no less than the finances of the central government, must be made to promote the aims of national policy. Nevertheless, Lord Balfour suggests, all can agree that the Budget is the central instrument of economic planning. The Chancellor's task, therefore, is a double one, in that he cannot afford to lose sight of the equally imperative need to create a financial climate in which enterprise can once again flourish. To say that is virtually the same thing as to say that the burden of taxation must be reduced, and Lord Balfour asks if these "various objectives" can be reconciled. Even more than before, he remarks, the key to everything is obviously a drastic cut in public expenditure. Drastic economies, the statement declares, are a prior condition of any lightening of the load of taxation, and it is equally clear that productive industry has the prior claim to any tax concessions which are thereby made possible. Over a vast range of industries, the statement goes on to say, such investment as has taken place has been made possible only by drafts on reserves and running into debt. So long as the calculation of taxable profits is based upon the cost of acquiring capital goods at some time in the past, and not upon the cost of replacing them at current prices, many industries cannot hope even to maintain their physical capital, far less to improve their productive apparatus.

Exports of Metals and Engineering Products

In a survey of the United Kingdom's export trade in 1952, the Board of Trade says that exports of metals and their manufactures in the fourth quarter were valued at £75,000,000. That was about £9,000,000 above the average for the first three-quarters of 1952 and brought the total for the year to £274,000,000, or 19 per cent more than in 1951. Exports of iron and steel in the fourth quarter reached a value of £54,000,000, which was £6,000,000 above the high total in the first quarter of the year and reflected the easing of the steel supply position. The total value for the year of exports of iron and steel and manufactures thereof, at £192,000,000, was 20 per cent above the 1951 total, although the actual weight of exports, 2,500,000 tons, was 4 per cent lower. Exports of non-ferrous metals last year were valued at £82,000,000, which was 17 per cent above the 1951 total. In the last quarter of 1952, however, non-ferrous metal exports, at £22,000,000, were 3 per cent below the first quarter's total, which included some special shipments to North America.

The Board of Trade survey goes on to show that exports in the broad category of engineering products last year amounted in value to £1,046,000,000, which represented an increase of 8 per cent over 1951. Last year, however, exports of vehicles—which account for nearly half the total value of engineering exports—only just reached the 1951 total, a high level of export in the first quarter being followed by a big reduction in the second and third quarters and only a slight recovery in the last quarter to a value which was still 8 per cent below the average for 1951. The bulk of the increase in the value of engineering exports last year, compared with 1951, was in machinery and electrical goods. The value of these two groups together increased by 16 per cent, and although they shared in the reductions of the second and third quarters, by the fourth quarter exports of machinery were 16 per cent above the average for 1951 and exports of electrical goods were 10 per cent more. Most of the increase in machinery exports was to the sterling area and Western Europe. Australia (£48,000,000), India (£36,000,000), and the Union of South Africa (£35,000,000) remained the principal markets for machinery, while exports to Italy (£12,000,000) and to Turkey (£10,000,000) were twice as much as in 1951.

Pre-War German Trade Marks

The Board of Trade has made a statement about pre-war German trade marks registered in the United Kingdom. It says that at the outbreak of war in 1939 there were over 4000 trade marks on the United Kingdom register of trade marks, the proprietors of which were German enemies. Except in certain special cases, these marks remained on the register during the war in the names of the German proprietors and have since been vested in the Custodian of Enemy Property for England. Subject to the protection of British and other Allied interests, it is now intended to clear the register of such of those marks as need no longer remain registered, and to return most of the remainder to the former German proprietors or their successors in title. The Board of Trade announcement indicates the procedure which will be followed to achieve these ends and sets out the action to be taken by the former German proprietors or by others interested in particular marks or desirous of objecting to their return to the former German proprietors. The marks will be treated individually; the Custodian will consider each case on its merits and makes no general promise that any particular mark will be cancelled or returned.

Broadly speaking, the procedure is that the former German proprietors of certain categories of marks, or their successors in title, should, if still interested in their marks, request the assignment of the marks to them by the Custodian. An opportunity will be given to British and other Allied interests to object to any such assignment before the Custodian acts on the requests. If a *prima facie* case is made out against the return of a mark to the former German proprietor or, in any case, if the mark in question was registered in Part A of the register since September 3, 1932, the Custodian, failing an acceptable agreement between the parties concerned, will not assign the mark to the former proprietor. But the latter can in such a case attempt to recover the registration by applying to the Registrar of Trade Marks for re-registration of the mark, and the Custodian will consider cancelling the existing registration to allow the application to proceed.

Coal Production

Coal output in Great Britain in the first three weeks of this year amounted to 13,846,500 tons, compared with 13,733,000 tons in the corresponding period of last year. The latest return by the Ministry of Fuel and Power shows that last week output from the deep mines was 4,407,000 tons and from opencast workings 233,400 tons, giving a total of 4,640,400 tons. This was 26,000 tons below the total production in the preceding week, but was an increase on the output of the corresponding week of 1952.

In the week ended January 17th the number of wage earners on colliery books was 721,700, of whom 299,100 were face workers. A year earlier the total number of wage earners was 703,100, of whom 287,100 were working at the face. Total absenteeism in the week ended January 17th is returned as 11·91 per cent, which was much the same as a year earlier, and output per manshift at the face was 3·15 tons. Total consumption in the same week, which included exports and bunkers, was 4,985,000 tons, and at the end of that week distributed stocks were 14,742,000 tons.

Notes and Memoranda

Rail and Road

MOTOR VEHICLE EXPORTS.—The Society of Motor Manufacturers and Traders has stated that the value of British cars and commercial vehicles exported last year reached an all-time record of nearly £190 million. In numbers, shipments of cars fell by almost 59,000 and of commercial vehicles by just over 8500, on the 1951 totals. Import restrictions in Australia and New Zealand accounted for the most part of the drop in car exports and also contributed to bringing down the volume of commercial vehicles shipped. Car sales last year to the U.S.A. numbered over 31,000, which was 11,500 more than in 1951, and higher truck and bus exports to Denmark, British West Africa and Turkey did much to offset the reduction in shipments to Australasia. Almost 70 per cent of car output and 53 per cent of commercial vehicle production went to overseas buyers during the year. Exports of agricultural tractors were up by over £1,000,000 on the 1951 total with a peak value of £42,250,000. The number of tractors sent abroad was 105,000.

Air and Water

I.N.A. AUTUMN MEETING.—The Council of the Institution of Naval Architects has accepted an invitation from Koninklijk Instituut van Ingenieurs to hold an autumn meeting in Holland between September 13 and 20, 1953.

WATTS' PRIZE.—The council of the Institution of Naval Architects announces that with the concurrence of the donors, Messrs. Watts, Watts and Co., Shipowners, London, awards from the Watts' Prize Fund will be made in 1953. Proposals for improving crews' or passenger accommodation should be sent to the Secretary, Institution of Naval Architects, 10, Upper Belgrave Street, London, S.W.1, by July 31, 1953.

MONSIEUR PIERRE DE MALGLAIVE.—We have learned with regret of the death, on January 18th, of Monsieur Pierre de Malglaive, who for a number of years was Agent General of the French Line in the United Kingdom. He was seventy-two. Monsieur de Malglaive was appointed managing director of the Compagnie Generale Transatlantique, Ltd., London, in 1934, and was elected chairman of the board in July, 1945. He retired at the end of 1949 and shortly afterwards returned to his home at Versailles.

AWARDS TO NAVAL INVENTORS.—The Admiralty has issued a Fleet Order encouraging Naval personnel to submit inventions and suggestions aimed at the improvement of the fighting efficiency of the Fleet. In suitable cases awards will be made from the Herbert Lott Naval Trust Fund, the income of which has considerably increased as a result of a legacy left by the founder of the fund. This fund was founded in 1930 by Mr. Herbert Lott, with a gift of £25,000. This provided an income of some £1200 a year, but when Mr. Lott died in July, 1947, he left a considerable sum of money to the fund, with the result that the income has now increased to more than £5000 a year. One of the purposes of the fund is to make awards to officers and men who contribute in signal degree to the improvement of the fighting appliances of the naval or marine forces of Her Majesty.

INSTITUTION OF NAVAL ARCHITECTS.—The spring meetings of the Institution of Naval Architects will be held on Wednesday, Thursday and Friday, March 25th, 26th and 27th, on board the "Wellington," the headquarters ship of the Honourable Company of Master Mariners, Victoria Embankment, London, W.C.2. The annual general meeting will take place at 10.15 a.m. on Wednesday and the annual dinner of the Institution will be held on Wednesday evening at 7.30 p.m. at the Connaught Rooms, Great Queen Street, W.C.2. The following is a provisional list of papers to be read: on Wednesday morning, "B.S.R.A. Resistance Tests on the 'Lucy Ashton,' Part II. The Ship Model Correlation for the Naked Hull Conditions," by Dr. J. F. Conn; on Thursday morning, "Large Dry Docks," by Mr. E. L. Champness, and "The Motion of an Aircraft Carrier at Sea in Relation to the Operation of Naval Aircraft," by Mr. J. L. Bartlett, and in the afternoon, "The Effect of Radial-Pitch Variation on the Performance of a Marine Propeller," by Professor L. C. Burrill and Mr. C. S. Yang, and "Fatigue in Ship Structures," by Mr. R. Weck; on Friday morning, "Water Forces on Submerged Bodies in Motion," by Mr. W. C. S. Wigley, and "A Skin Friction Determination Using Wall Sided Models of Great Draught," by Mr. R. T. Shiells, followed in the afternoon by "Refrigeration," by Mr. J. D. Farmer, and Mr. K. C. Hales and "Sea Trials of a Victory Ship 'A.P.3' in normal Merchant Service," by Professor G. Aertssen. The Friday afternoon session will be a joint meeting with the Institute of Marine Engineers.

AIR TRAFFIC IN THE UNITED KINGDOM, AUGUST, 1952.—British European Airways carried more passengers in August, 1952, than in any previous month, and 25 per cent more than in August, 1951. Over 200,000 passengers were carried and they travelled a total of more than 50,000,000 miles. On the Corporation's domestic routes the increase in passenger traffic was 36 per cent. International passenger traffic increased by 20 per cent, despite the fact that the total volume of air travel to and from the Continent was lower. Besides this improvement in passenger results there were smaller increases in freight and mail traffic. The increased traffic did not altogether take up the 30 per cent additional capacity operated, but though load factors were lower the overall figure for all operators was still above 65 per cent. British Overseas Airways Corporation flew nearly 100,000,000 passenger-miles in the five weeks July 27th to August 30th. Compared with a corresponding figure for 1951 this represented an effective increase of about 20 per cent. Passenger traffic on the western routes rose from 27,000,000 passenger-miles in August, 1951, to 44,000,000 in the thirty-five-day period now reported. Freight and mail traffic also improved. On the eastern routes both passenger and freight traffic showed an effective rise of between 5 and 10 per cent, but the volume of mail carried was little higher than in 1951. The services of independent companies associated with the Corporations extended over more than 11,000 route-miles, or double the 1951 figures. Total capacity operated was 39 per cent higher and traffic 36 per cent higher. Seat-miles available were increased by more than 100 per cent to nearly 6,500,000, and passenger-miles flown increased by nearly 150 per cent to over 4,750,000.

Miscellanea

CAVITATION.—There was a misprint in the legend below Fig. 1 of the article "Cavitation," by E. Crewdson, which appeared in last week's issue. The legend read "Initial pressure in bubble 3·2 p.s.i." This should have read "Initial pressure in bubble 0·2 p.s.i."

ENGINEERING EDUCATION BULLETIN.—The Manchester College of Technology has now published the third issue of the *Bulletin of Mechanical Engineering Education*. Professor H. Wright Baker and Mr. K. L. Johnson have collaborated in its preparation and its contents include papers on a variety of subjects which cannot fail to be of interest both to engineering teachers and students.

THE ROYAL SHOW.—The Royal Agricultural Society states that at a recent meeting in Blackpool, a local appeal fund was launched in connection with this year's Royal Show, which is to be held there in July. The actual showground covers an area of 160 acres, and the machinery and other trade exhibitors will number more than 600. The "Royal" was last held in Lancashire—at Manchester—in 1930.

THE FIRST POLYTHENE INSULATED CABLE.—On January 28th, the first "Telcothene" (polythene) insulated carrier-frequency multi-quad land communication cables in the world were formally handed over. The two cables, each about 20 miles long, were laid last year, between Copenhagen and Roskilde, by the Telegraph Construction and Maintenance Company, Ltd., of Greenwich. They provide a capacity of over 1000 circuits.

AUSTRALIAN INDUSTRIAL EXPANSION.—According to a statement by Mr. Howard Beale, Acting Minister for National Development, seven Australian manufacturing industries are planning an expansion programme involving the investment of £A215,000,000. He said that these industries were petrol refining, £A80,000,000; metals, £A50,000,000; engineering, £A40,000,000; paper, £A10,000,000; and chemical, cement and fertilisers, £A25,000,000.

SKYLINE IN KENT.—We have received from E. B. Badger and Sons, Ltd., the managers of the refinery project of the Anglo-Iranian Oil Company, Ltd., on the Isle of Grain, Kent, an illustrated brochure entitled "New Skyline in Kent." The problems encountered during the construction of the refinery are briefly outlined, photographs illustrate various sections of the work and diagrams in colour show the three phases of construction and the flow line of the products.

BRITTLE FRACTURE IN STEEL.—The West of Scotland Iron and Steel Institute is to hold a one-day conference on "Brittle Fracture in Steel," on Friday, May 15th. Papers have already been promised from the U.S.A., Sweden and Belgium as well as from the United Kingdom. A more detailed announcement will be made shortly; meanwhile those interested in the conference are asked to notify the secretary of the Institute, at 39 Elmbank Crescent, Glasgow, C.2.

DEATH OF MR. C. B. REID.—It is with regret that we note the death of Mr. C. B. Reid, the editor of *The Surveyor* and chairman of the St. Bride's Press, Ltd., with which he had been associated for over half a century. Charles Blackhall Reid was born on March 22, 1879, and he joined the editorial staff of *The Surveyor* in 1899, a few years after it was founded. He became editor in 1917, was elected to the board of the St. Bride's Press, Ltd., in 1934, and succeeded to the chairmanship in February, 1952.

A HEAVY DUTY FOOT SWITCH.—A new foot switch which is now being made by the H. G. Poxon Engineering Company, Ltd., 1, Northolt Road, Harrow, Middlesex, is designed for heavy workshop duty and is rated at 20A up to 250V d.c. or a.c. It is built up of substantial light alloy castings and has rubber feet, which can be screwed to the floor if desired, whilst the cable grip is suitable for T.R.S. flexible cable of various sizes. The heavy duty toggle action switch built into the unit has quick make and break wiping contacts of either single or double-pole design as specified.

CONFERENCE ON HEAT CONSERVATION.—The Combustion Engineering Association is to hold a conference at the Grand Hotel, Harrogate, on Wednesday and Thursday, February 11th and 12th, on "Heat Conservation in the Generation, Distribution and Utilisation of Steam in Industry." On the first day the subjects for discussion are "Steam Generation" and "Steam Distribution," and on the second day the conference will consider "Steam Utilisation" and "Heat Transfer and Heat Insulation." The fee for the conference is £2 2s. Full details can be obtained from the Combustion Engineering Association, 6, Duke Street, St. James's, London, S.W.1.

FIRE RESISTANCE OF CONCRETE FLOORS.—The U.S. National Bureau of Standards has issued a report by D. S. Goalwin entitled *Fire Resistance of Concrete Floors*. It is intended to aid building authorities in evaluating the fire-resistance characteristics of concrete floor constructions and to give designers and builders a basis for the selection of constructions which will meet fire resistance requirements. The increasing use of concrete slab floors in industrial and commercial building and multiple residential dwellings makes adequate fire-resistance ratings of these components desirable. Full-scale tests were made in accordance with the American Society for Testing Materials and the American Standards Association specifications for fire tests. The report covers the results of eleven small-scale and four full-scale fire-endurance tests on monolithic concrete floors made with siliceous-gravel aggregates. The tests on the small-scale reinforced slabs of 4in to 8in thickness were carried out primarily to determine the relationship between floor thickness and fire resistance. It is stated that among the slabs were a series of six 2½in and 3in thick floors tested to determine the fire-resistance of concrete floors constructed with prefabricated lightweight concrete joists.

Personal and Business

VEEDER-ROOT, Ltd., Dundee, states that Mr. R. M. Garland, chief engineer, has been appointed a director.

THOS. W. WARD, Ltd., Sheffield, states that it has been appointed official general distributor of "Staffa" mobile cranes and "Wetherill-Hydraulic" loading shovels.

ADDRESSOGRAPH-MULTIGRAPH, Ltd., announces the completion of the building of its new factory and head office at Maylands Avenue, Hemel Hempstead, Herts.

MR. GEORGE WILSON, deputy chairman and managing director of Raleigh Industries, Ltd., has been appointed a governor of the Loughborough College of Technology.

MR. C. W. J. CLARIDGE, A.M.I.Mech.E., has been appointed sales engineer of Commer Cars, Ltd., and Karrier Motors, Ltd., Luton, in succession to the late Mr. A. H. Glaspole.

ALUMINIUM WIRE AND CABLE COMPANY, Ltd., states that it has opened a branch office at Transreef House, 66, Marshall Street, Johannesburg. Mr. E. Hall is in charge of the branch.

BRITISH INSULATED CALLENDER'S CABLES, Ltd., states that Mr. R. L. Packer has taken up his duties as London branch manager. He succeeds Mr. F. Samuel, who is retiring on March 8th.

MR. JAMES HODGE, A.M.I.Mech.E., A.F.R.Ae.S., senior consultant of Power Jets (Research and Development), Ltd., is going to Columbia University, New York, for four months as visiting lecturer on gas turbines.

ADAM AND HARVEY (RAPID HAMMER), Ltd., informs us that, as from February 16th, its address will be Greenwich House, 10–13, Newgate Street, London, E.C.1 (telephone, City 6671; telegrams, "Adarvey, Cent, London").

MR. A. ROBERT JENKINS has been appointed managing director of Robert Jenkins and Co., Ltd., Rotherham, in succession to the late Mr. Ernest Twigg. He is also managing director of the firm's subsidiary, the Rotherham Motor Company, Ltd.

MR. A. D. LIDDERDALE, A.M.I.Mech.E., has relinquished his appointment with the A.P.V. Company, Ltd., to become chief mechanical engineer of the Telegraph Construction and Maintenance Company, Ltd., Telcon Works, Greenwich, S.E.10.

MR. DOUGLAS STANTON MACFARLANE has been appointed a director of James Howden and Co., Ltd., and James Howden and Co. (Land), Ltd. In addition to his present duties Mr. D. S. Macfarlane will be in charge of the marine side of the business.

C. A. PARSONS AND CO., Ltd., Newcastle upon Tyne, states that Mr. G. M. Baker, general works manager, has been appointed a director. Mr. J. L. Packard has been appointed manager of the London office in succession to Mr. E. P. Preston, who retired on December 31st.

THE BRITISH ELECTRICITY AUTHORITY states that Mr. P. Briggs, M.Inst.F., chief generation engineer (operation), S.E. Division, has been appointed controller of the Merseyside and North Wales Division. He succeeds Mr. W. A. Gallon, M.I.E.E., who has been appointed deputy chairman of the South Wales Electricity Board.

LAURENCE, SCOTT AND ELECTROMOTORS, Ltd., states that Mr. P. Webb has been appointed manager of the London office. For some time he has been chief estimator in the company's A.C. department, in which position he is succeeded by Mr. G. E. Sawyer. There are no changes in the staffs of the company's industrial, marine and export departments of the London office, which are now grouped together at Manfield House, Southampton Street, Strand, W.C.2.

METROPOLITAN-VICKERS ELECTRICAL COMPANY, Ltd., Trafford Park, Manchester, announces the following appointments:—Mr. G. D. Harradine, sales manager, industrial control department, in succession to Mr. C. H. de Nordwall; Mr. H. W. Hardern, M.I.E.E., assistant chief engineer, transformer department; Mr. E. L. N. Towle, M.I.Mech.E., M.I.E.E., assistant chief engineer (industrial), electrical general engineering department; Mr. F. B. Holt, A.M.I.E.E., consultant (industrial), electrical general engineering department.

British Patent Specifications

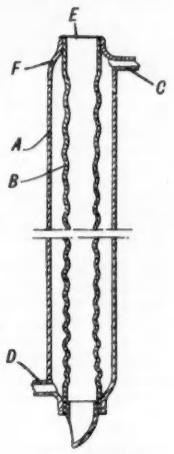
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 2s. 8d. each.

STEAM GENERATORS

684,602. March 14, 1949.—Heat Exchanger Elements for Steam Boilers, Giovanni Rossi, 65, Via della Stazione, Valle Lomellina, Pavia, Italy.

With reference to the drawings, the external tubular body of the element is shown at *A*, whilst *B* represents the internal body forming the smoke tube. The body has at or near its ends tubes *C* and *D* for the water and steam outlet and for the water inlet respectively. Smoke enters the inner tubular body *B* at the top and is discharged at the bottom so as to provide a circulation of fluids in countercurrent. In a boiler, the tubes *C* and *D* of all the elements lead into headers. An outlet for cleaning and for the removal of mud is provided. In each of the elements the upper opening *E* is coaxial with the body, and the rim of this opening is welded to the domed or convex end *F* of the body. The lower end of the tube *B* may appropriately be bent so that it leads laterally through the wall of the body *A*, and provides an uninterrupted flow for the smoke. In order to prevent deformation due to the expansion under the action of heat, and to create eddy currents in the smoke, the smoke tube is corrugated. Modified designs are also shown in the specification.—*December* 24, 1952.

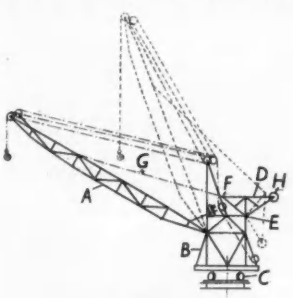


No. 684,602

CRANES AND LIFTING DEVICES

685,351. February 15, 1950.—Jib Crane, Allmanna Svenska Elektriska Aktiebolaget, of Vasteras, Sweden. (*Inventor : Julius Gotzlinger.*)

Referring to the drawing, the jib of the crane *A* and the crane tower *B* are rotatable on rollers *C*. A triangular counter-balancing member *D* for the jib is pivoted to the tower at the corner *E*. At the other corner *F* one end of a cable *G* is pivotally attached, the other end being attached to the jib at a distance from the top of about one-third of the length. A counter-weight *H* is attached to the member *E* at the corner. The inclination of the jib is varied by machinery in the tower by using a screw-threaded



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shaft. Other means may be provided for the balancing of the load, independently of the balancing of the jib and it is possible to attain very efficient balancing of the jib so that the machinery for moving the jib, and with it the load, may be reduced in size. The cable to the hook is run in a suitable way to obtain a horizontal movement of the load when the inclination of the jib is varied. The full and dash lines show the jib in different inclinations. Although the invention is described in connection with a swing crane, it is, of course, also applicable to other jib cranes.—*December* 31, 1952.

METALLURGY

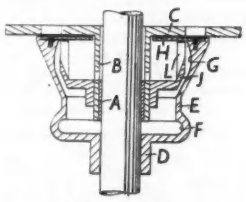
685,325. July 11, 1950.—The Manufacture of Steel, Hüttenwerk Oberhausen Aktiengesellschaft, Oberhausen, Germany.

The specification describes a method of manufacturing steel having a nitrogen content below 0·010 per cent in a converter with an air blast enriched with oxygen. The additional oxygen is supplied to the molten iron as blowing proceeds in such a manner that when the pig iron has a normal content of accompanying elements the percentage oxygen content of the air blast is raised by at least one additional per cent for each 1 per cent of carbon burned. At least the proportion of oxygen in the air blast reached at the end of the period of decarbonisation is maintained until the end of the blowing operation. When the proportion of accompanying elements in the pig iron exceeds the normal, the percentage of oxygen content of the air blast is increased correspondingly. This supply of additional oxygen to the air blast being partly effected by the addition of oxygen in combined solid form such as oxidic ores or scale in quantity such as to avoid both overheating and under-cooling of the bath and to obtain a final temperature ensuring good casting properties for the steel.—*December* 31, 1952.

BEARINGS AND SUPPORTS

684,971. March 31, 1950.—Lubrication of Plain Bearings for Vertical Shafts, The Glacier Metal Company, Ltd., 368, Ealing Road, Alperton, Wembley, Middlesex. (*Inventor : Phil Prince Love.*)

As shown in the drawing, a vertical shaft has a bearing bush *A* mounted in the lower part of a tubular housing *B* provided with a mounting flange *C* at its upper end. Below the bearing a boss *D* is fixed on the shaft, formed integrally with a spinner cup *E* of substantially greater diameter than the housing and extending upwards to above the bearing. The lower part of the spinner cup provides an oil reservoir and may have an annular groove or enlargement *F* at its lower part to provide for the collection and retention of dirt or other foreign matter. From



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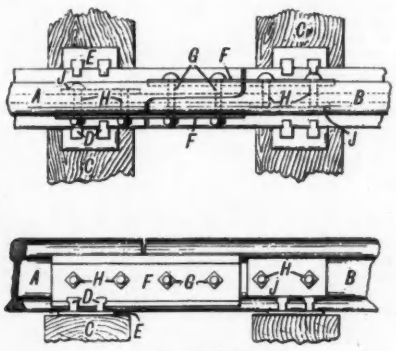
the lower part the spinner cup *E* is flared outwards and upwards so that by centrifugal action the oil is lifted. The inner surface of the cup may be curved inwardly at *G*. An annular ring *H* is fixed to the top of the cup to prevent escape of oil from the system. An oil-collecting cup *J* fixed to the tubular housing *B* communicates with a space above the bearing or with oil channels. The collecting cup *J* has baffle elements *L* arranged so that the oil carried into the upper part of the spinner cup encounters the baffle elements and is caused to drop into the collecting cup, from which it flows to the bearing by gravity. If desired, the centrifugal action may be accentuated by the provision of internal blades in the spinner cup.—*December* 31, 1952.

RAILWAY ENGINEERING

685,155. August 21, 1950.—Rail Joints, Alfred Nathan Brogden, 142, St. Anne's Road East, St. Annes-on-Sea, near Blackpool.

The invention concerns a rail joint in which securing fish-plates are offset or staggered in relation to each other, so that each fish-plate extends an equal or substantially equal distance on each side of the adjacent rail gap. Referring to the drawings, a pair of adjacent rail sections *A* and *B* resting on



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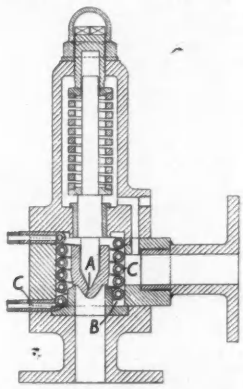
sleepers *C* and secured by spikes *D* passed through plates *E* on which the rail lies, are shown. The adjacent ends of rails are reduced to half-width to minimise the shock of passage of the wheels from one rail section to the next. The rail-connecting fish-plates *F* support the rail joint and, as shown, are offset or staggered in relation to each other. The fish-plates are of four-hole type and, as shown, six bolts are employed to secure them in position, the middle two bolts *G* being common to both plates. In order that the bolts *H* securing the outer ends of the fish-plates do not damage the rail webs, spacing or protector plates *J* are provided. The method of connecting adjacent rail ends locks them rigidly and securely and prevents relative movement of the rail ends.—*December* 31, 1952.

VALVES

685,722. June 23, 1950.—Safety Valves, Cockburns, Ltd., James Rodger and Thomas Grant, all of the company's address at Clydesdale Engineering Works, Cardonald, Glasgow, S.W.2.

The invention relates to safety valves for use with fluids which, on release by the safety valve, tend to freeze upon the valve proper, or closure member, and its seat and within the outlet from the valve chest. Referring to the drawing, *A* is the valve



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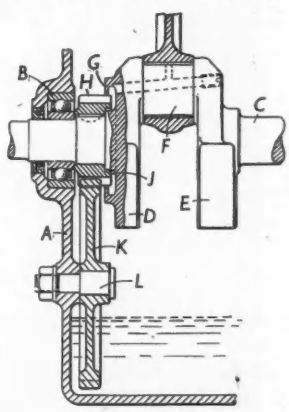
movable in a valve chest *B* containing a tubular heating coil *C* forming a heat exchanger and surrounding the closure member. Terminal portions of the coil extend outside of the valve chest and are connected, respectively, to a source of heating fluid, such as steam, and to the exhaust. The heating coil also surrounds the valve seat adjacent to the valve member. The general construction of the valve chest, the cover and flanges, also the stressed loading spring, are clearly shown in the drawing.—*January* 7, 1953.

INTERNAL COMBUSTION ENGINES

685,252. November 4, 1950.—Lubricating System for Internal Combustion Engines, The Birmingham Small Arms Company, Ltd., Armoury Road, Small Heath, Birmingham. (*Inventor : John Wadsworth Harrison.*)

The invention relates to the lubrication of crankpins. As shown in the drawing, a crankcase *A* houses a ball bearing assembly *B* which supports one end of a crankshaft *C* having webs *D* and *E* and a crank-pin *F*. Formed in the outer face *G* of the web *D* is an annular recess which is undercut



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radially outwardly. From the recess a hole, as shown, leads to the surface of the crank-pin via a hole drilled perpendicularly from the outer surface of the pin. The end of the hole is plugged by a grub screw. Keyed to the crankshaft between the flange *D* and the bearing assembly *B* is a gear-wheel *H*, which is roughly the same size as the bearing assembly, and having a rim *J* and teeth

projecting laterally into the recess in the web. Meshing with the gearwheel is a lower gearwheel *K* rotatably mounted on a stud *L*. The lower part of the crankcase forms the oil reservoir or sump and is filled with oil to the level indicated, which is appreciably below the path of the crankshaft and slightly below the stud. In operation, as the lower gearwheel is rotated by the upper wheel it carries a certain amount of oil on its teeth. When those teeth carrying the oil mesh with the teeth of the upper gearwheel the oil is exuded laterally and into the recess in the crank web *D*. Under the action of centrifugal force the oil is impelled to the outermost side of the recess and from there to the holes leading to the surface of the crank-pin. A certain amount of oil is exuded from the sides of the gear wheels remote from the crank web and, as the upper gearwheel is close to and substantially the same size as the bearing, this oil may be arranged to discharge into the bearing for lubricating purposes.—*December 31, 1952.*

Contracts

THE UNITED STEEL COMPANIES, Ltd., announces that its Samuel Fox branch, Stocksbridge, Sheffield, has secured a contract for the supply of razor strip to Gillette Industries in the United States of America. The initial contract calls for the supply of 45 tons per month, for six months, of razor strip, which should make between 60 and 65 million razor blades. The monthly value of this order will be about £16,100, the total value of the order being £96,600.

TAYLOR WOODROW CONSTRUCTION, Ltd., has been awarded a contract for the superstructure of the nine-storied air traffic control building to be built at London Airport. The contract will be carried out under the Air Ministry Works Directorate for the Ministry of Civil Aviation. Taylor Woodrow is also constructing the foundations for this and two other permanent buildings, the consulting engineers for which are Sir William Halcrow and Partners. They are the first of a group of traffic handling buildings designed by Mr. Frederick Gibberd, F.R.I.B.A., M.T.P.I., on behalf of the Ministry of Civil Aviation.

GLASGOW CORPORATION has awarded a contract valued at £276,541 to Kinnear, Moodie and Co., Ltd., for the construction of a tunnel under the Clyde. The tunnel, which is part of Glasgow's new West Main Works, at present under construction, will be driven under the Clyde at a point about half-a-mile west of the Whiteinch Ferry. It is designed to accommodate two 36in diameter water mains and will have an internal diameter of 12ft, with 18ft diameter shafts at each end. The tunnel and shafts will be composed of cast iron segments forming rings 20in deep. The tunnel will be 345 yards long and each shaft approximately 100ft deep. It will be about 40ft below the deepest part of the present river bed and will be 10ft below the maximum proposed dredged level for the future. Much of the construction work will require to be carried out in compressed air at about two-and-a-half times normal atmospheric pressure. About 1400 tons of cast iron segments will be used and they are to be supplied by the Stanton Ironworks Company, Ltd. At present only one main will be laid in the tunnel, supplied by Stewarts and Lloyds, Ltd. It will consist of about 230 tons of 36in diameter steel pipe spun lined and bitumen sheathed. An official starting date has been given for the project but work cannot begin until an Order is granted by the Secretary of State for Scotland. The time of construction will be two years. The design and construction of the tunnel is under the direction of the consulting engineers, Messrs. Mott, Hay and Anderson, in collaboration with the chief engineer and general manager of the Water Department, Mr. Stanley D. Canvin. The department also recently announced the award of two contracts valued at £107,402, to James Miller and Partners, Ltd., comprising the laying of 4 miles of 36in diameter concrete-lined cast iron water main and including the erection of a bridge to carry it over a main railway line in Scotstounhill, Glasgow. The principal contracts for the supply of pipes have been placed with the Staveley Iron and Chemical Company, Ltd., and are valued at £131,500. Short lengths of steel pipe to the value of £2600 will be used for special works and are being supplied by Stewarts and Lloyds, Ltd. Orders for valves of value £5150 were placed some two years ago with Glenfield and Kennedy and they should become available as the work proceeds. The construction of this part of the department's west main works will complete the pipe-laying work of the whole 10 miles of main with the exception of the crossing of the River Clyde. The engineer for all these works is Mr. Canvin.

NEW RADIOACTIVE MINERAL.—The discovery of a new kind of mineral very rich in the radioactive elements thorium and uranium was announced recently at the Mineralogical Society by Mr. S. H. U. Bowie and Mr. J. E. T. Horne, of the Geological Survey and Museum, Department of Scientific and Industrial Research. Recognition of a new mineral species is a rare event. It is stated that the mineral contains 31 per cent thorium oxide and 4 per cent uranium oxide. It has been named cheralite, from Chera, the ancient name of the State of Travancore, in South India, where the new species was found. The deposit of the mineral is unfortunately much too small to be of any commercial importance. A specimen of the new mineral is on display in the Geological Museum, South Kensington, London, S.W.7. It is of a dull green colour, in lumps an inch or two in size. Mineralogically it is related to monazite, the commonest ore of thorium.

Launches and Trial Trips

POLARTANK, oil tanker; built by Barclay, Curle and Company, Ltd., for Melsom and Melsom, Norway; length 566ft, breadth 72ft 6in, depth 40ft 6in, deadweight 19,000 tons; Barclay Curle-Doxford oil engine, six cylinders, 750mm diameter by 2500mm combined stroke, two cylindrical multi-tubular boilers. Launch, December 20th.

GUILDFORD, motor collier; built by the Burntisland Shipbuilding Company, Ltd., for the South Eastern Gas Board, London; length between perpendiculars 264ft 6in, breadth moulded 39ft 5in, depth moulded 18ft 6in, deadweight 2875 tons, draught loaded 17ft 1¼in; three cargo holds, self-trimming hatchways; British Polar diesel engine, eight cylinders 340mm diameter by 570mm stroke, 1150 b.h.p, at 225 r.p.m. Trial, January 15th.

GRINDEFJELL, cargo ship; built by John Crown and Sons, Ltd., for Olsen and Ugelstad, Norway; length between perpendiculars 250ft, breadth 42ft 6in, depth moulded to upper deck 26ft; 2750 tons deadweight on 18ft 3in draught; two Clark-Sulzer diesel engines. Launch, January 16th.

HELIX, oil tanker; built by Swan, Hunter and Wigham Richardson, Ltd., for the Anglo-Saxon Petroleum Company, Ltd.; length between perpendiculars 530ft, breadth moulded 69ft 3in, depth moulded 39ft, draught loaded 29ft 7¼in, deadweight 18,000 tons; one set of B.T.H. turbo-electric machinery, two turbo-alternators, one propeller motor of 8300 s.h.p. at 103 r.p.m. maximum, 7500 s.h.p. at 100 r.p.m. normal service, two Babcock and Wilcox boilers. Launch, January 16th.

CORBURN, motor collier; built by the Goole Shipbuilding and Repairing Company, Ltd., for William Cory and Son, Ltd.; length between perpendiculars 258ft, breadth moulded 39ft 3in, depth moulded 19ft, deadweight 2700 tons; British Polar diesel engine, Mark M. 48 M, 1040 b.h.p. at 205 r.p.m. Launch, January 17th.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office on or before the morning of the Monday of the week preceding the meetings. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

Mon., Feb. 4th.—N.E. LONDON BRANCH: Angel Hotel, Ilford, "Modern Fluorescent Lighting," D. E. Mutch, 8 p.m.
Tues., Feb. 3rd.—S.E. LONDON BRANCH: Eltham Congregational Church Hall, Court Road, Eltham, "Electricity Regulations and Electrical Safety," S. J. Emerson, 8 p.m.——W. LONDON BRANCH: Windsor Castle Hotel, 134, King Street, Hammersmith, London, W.6, "Jointing and Compounds," B. A. Masted, 7.30 p.m.——NOTTINGHAM BRANCH: E. Midland Electricity Board, Smithy Row, Nottingham, "Some Recent Developments of Electronic Equipment for Industry," R. J. F. Howard, 7.30 p.m.
Wed., Feb. 4th.—N. LONDON BRANCH: Three Jolly Butchers Hotel, Wood Green, London, N.22, "National Apprenticeship Scheme," A. R. Secombe, 8.15 p.m.
Thurs., Feb. 5th.—S. LONDON BRANCH: Cafe Royal, North End, Croydon, "Flame-proof Motors," A. N. D. Kerr, 8 p.m.

BRITISH INSTITUTION OF RADIO ENGINEERS

Thurs., Feb. 5th.—SCOTTISH SECTION: Department of Natural Philosophy, The University, Edinburgh, "The Principle of Electronic Computing Machines," B. V. Bowden, 7 p.m.——MERSEYSIDE SECTION: Electricity Service Centre, Whitechapel, Liverpool, "A Port Radio-Telephone System," D. G. Holloway, 7 p.m.

CHEMICAL SOCIETY

Thurs., Feb. 5th.—LONDON BRANCH: Burlington House, Piccadilly, London, W.1, Symposium, "Acetylene Chemistry," arranged by E. R. H. Jones, 7.30 p.m.

CLEVELAND INSTITUTION OF ENGINEERS

Mon., Feb. 2nd.—Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, "Gas Turbines and Their Applications in Iron and Steel Works," F. E. Baumann, 6.30 p.m.

ELECTRIC RAILWAY SOCIETY

Thurs., Feb. 5th.—Fred Tallant Hall, 153, Drummond Street, London, N.W.1, "The Swiss Federal Railways," C. Smith, 7.15 p.m.

ILLUMINATING ENGINEERING SOCIETY

To-day, Jan. 30th.—BIRMINGHAM CENTRE: "Regent House," St. Philip's Place, Colmore Row, Birmingham, "Whither Lighting Design," A. J. P. Pashler and J. R. Anstey, 6 p.m.
Tues., Feb. 3rd.—STOKE-ON-TRENT GROUP: Midlands Electricity Board, 31, Kingsway, Stoke-on-Trent, "Glass in the Service of Light," A. J. Holland, 6 p.m.
Wed., Feb. 4th.—EDINBURGH CENTRE: Lighting and Cleansing Department, 357, High Street, Edinburgh, "Luminescence as Applied to Lighting," H. G. Jenkins and A. H. McKeag, 7 p.m.——NEWCASTLE CENTRE: Minor Durrant Hall, Oxford Street, Newcastle upon Tyne, 1, "Lighting and Vision as Age Advances," H. C. Weston, 6.15 p.m.
Thurs., Feb. 5th.—GLASGOW CENTRE: Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2, Annual General Meeting, "Luminescence as Applied to Lighting," H. G. Jenkins and A. H. McKeag, 6.30 p.m.——NOTTINGHAM CENTRE: E. Midlands Electricity Board, Smithy Row, Nottingham, "New Lamps, New Uses and New Lighting Techniques," H. R. Ruff, 6 p.m.——EXETER GROUP: Providence Hall, Norhernhay Street, Exeter, "Fluorescent Street Lighting—The First Five Years," H. E. G. Watts, 7 p.m.
Fri., Feb. 6th.—BATH AND BRISTOL CENTRE: S.W. Electricity Board Lecture Theatre, Old Bridge, Bath, "Fluorescent Street Lighting—The First Five Years," H. E. G. Watts, 7 p.m.——HUDDERSFIELD GROUP: Electricity Showroom, Market Street, Huddersfield, "Sodium Lamps and Their Applications," A. W. Gostt, 7.15 p.m.

INCORPORATED PLANT ENGINEERS

Tues., Feb. 3rd.—LONDON BRANCH: Royal Society of Arts, John Adam Street, Adelphi, Strand, W.C.2, "Selection, Installation and Maintenance of Small Diesel Engines," D. C. Edwards, 7 p.m.——EDINBURGH BRANCH: 25, Charlotte Square, Edinburgh, "Preventive Maintenance—the British and American Approach," T. C. Robinson, 7 p.m.——S. WALES BRANCH: S. Wales Institute of Engineers, Park Place, Cardiff, "Water Treatment," 7.15 p.m.
Wed., Feb. 4th.——SOUTHAMPTON BRANCH: Polygon Hotel, Southampton, "Electronics in Industry," with Films, 7.30 p.m.
Thurs., Feb. 5th.—PETERBOROUGH BRANCH: Eastern Gas Board's Demonstration Theatre, Church Street, Peterborough, "Processed Steam," E. S. Chandler, 7.30 p.m.

INSTITUTE OF ECONOMIC ENGINEERING

Sat., Feb. 7th.—The Christian Institute, 70, Bothwell Street, Glasgow, "Production Incentives," J. Binnie, 10.30 a.m.

INSTITUTE OF MARINE ENGINEERS

Tues., Feb. 3rd.—JUNIOR LECTURE: S.E. London Technical College, Lewisham Way, London, S.E.4, "Diesel-Hydraulic Propulsion," F. J. Mayor, 8 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Mon., Feb. 2nd.—SCOTTISH CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2, "Notes on Purchasing Procedure and Problems," A. Craig McDonald, 7.30 p.m.
Tues., Feb. 3rd.—EASTERN CENTRE: Marshalls Airport, Cambridge, Open Discussion Meeting, 7 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

Sat., Jan. 31st.—MIDLANDS BRANCH: The University, Edmund Street, Birmingham, Annual General Meeting, "The Treatment of Waste Gases in Chemical Industry," W. A. Damon.

INSTITUTION OF CIVIL ENGINEERS

Tues., Feb. 3rd.—ROAD MEETING: Great George Street, Westminster, London, S.W.1, "Some Aids to Traffic Movements," R. A. B. Smith, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Mon., Feb. 2nd.—S. MIDLAND CENTRE: James Watt Memorial Institute, Great Charles Street, Birmingham, "Application of Iron-Cored Coils as Control and Circuit Elements," P. J. Hetzel; "Arc Quenching Circuits," B. H. Stonehouse; "Machines, Animals and Information," B. de Ferranti, 6 p.m.
Tues., Feb. 3rd.—MEASUREMENTS AND SUPPLY SECTIONS: Savoy Place, London, W.C.2, "A Moving Coil Relay Applied to Modern High-Speed Protective Systems," C. Ryder, J. Rushton and F. M. Pearce, 5.30 p.m.——N. MIDLAND CENTRE: British Electricity Authority, 1, Whitehall Road, Leeds, 1, Informal Discussion, "Electric Winders and the Supply Authority," opened by D. R. Love and L. Abram, 6.30 p.m.
Thurs., Feb. 5th.—ORDINARY MEETING: Savoy Place, London, W.C.2, "The First Stage of the Electrification of the Estrada de Ferro Santos a Jundiai (Late Sao Paulo Railway)," R. J. H. Chatterton and D. H. Rooney, 5.30 p.m.

INSTITUTION OF ENGINEERING INSPECTION

Tues., Feb. 3rd.—COVENTRY BRANCH: Room A.5, Technical College, Coventry, "Precision Measurements," W. Foster, 7.30 p.m.——S.W. BRANCH: Grand Hotel, Broad Street, Bristol, "The Manufacture and Properties of Natural and Synthetic Rubber Compounds," L. G. Shelton, 7.30 p.m.
Wed., Feb. 4th.—BIRMINGHAM BRANCH: Chamber of Commerce, New Street, Birmingham, "Evolution of the Watch and the Modern Methods Now Employed During Manufacture," 7.30 p.m.
Thurs., Feb. 5th.—LONDON BRANCH: Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2, "Education and Training for the Inspection Branch of Engineering," G. V. Stabler, 6 p.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

Tues., Feb. 10th.—39, Elmbank Crescent, Glasgow, C.2, "Cranes," J. Patrick, 6.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, Jan. 30th.—Storey's Gate, St. James's Park, London, S.W.1, Discussion on "Scale Formation in Sea-Water Distilling Plants and its Prevention," H. Hillier, 5.30 p.m.

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Wed., Feb. 4th.—Conference Room, 4th Floor, Waterloo Bridge House, London, S.E.1, "Methods of Investigation in the Telephone Branch Circuit Laboratory," M. Mitchell, 5 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

To-day, Jan. 30th.—MIDLAND COUNTIES BRANCH: James Watt Memorial Institute, Great Charles Street, Birmingham, "Further Recent Midland Structures," 7 p.m.
Tues., Feb. 3rd.—NORTHERN COUNTIES BRANCH: Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, "Electricity Generating Stations," B. A. E. Hiley, 6.30 p.m.
Wed., Feb. 4th.—NORTHERN COUNTIES BRANCH: Neville Hall, Newcastle, "Electricity Generating Stations," B. A. E. Hiley, 6.30 p.m.

INSTITUTION OF THE RUBBER INDUSTRY

Mon., Feb. 2nd.—N.E. SECTION: Neville Hall, the Mining Institute, Neville Street, Newcastle upon Tyne, "The Neoprene Lattices—Their General Characteristics, Compounding and Processing," W. G. Vennells, 7 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, Jan. 30th.—Townsend House, Greycoat Place, London, S.W.1, "Metal Spinning," R. E. Baskerville, 7 p.m.
Fri., Feb. 6th.—Townsend House, Greycoat Place, London, S.W.1, Film Evening, "Depositing Stellite with the Oxy-Acetylene Flame," 7 p.m.

MANCHESTER ASSOCIATION OF ENGINEERS

To-day, Jan. 30th.—Engineers' Club, Albert Square, Manchester, 2, Films, "Construction of the Stanlow Refinery" and "The Failure of the Tacoma Narrows Bridge," 6.45 p.m.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

To-day, Jan. 30th.—Bolbec Hall, Newcastle upon Tyne, 1, "Thickness of Tubes for Water-Tube Boilers," D. W. Crancher, 6.15 p.m.

PURCHASING OFFICERS ASSOCIATION

Tues., Feb. 3rd.—OXFORD AND BUCKS GROUP: Red Lion Hotel, High Wycombe, Film Show, "Steel Industry," 7.30 p.m.
Wed., Feb. 4th.—COVENTRY BRANCH: Geisha Cafe, Coventry, Lecture and Films, "Fabrication of Aluminium Alloys" and "This is Aluminium," 7.30 p.m.——TYNESIDE BRANCH: Crown Hotel, Clayton Street, Newcastle upon Tyne, "Scientific Management," R. S. Ross, 7 p.m.